

2018
EDITION
For 2019 Exam

TRUEMAN'S

ELEMENTARY BIOLOGY

Vol. II for Class XII



K.N. Bhatia • M.P. Tyagi



A Trueman Publication

Published by
Trueman Book Company
Opposite Arya Samaj Mandir
Adda Hoshiarpur, Jalandhar (Pb) Pin : 144 008
Branch Office : 4353/4-C, Ansari Road, Daryaganj, New Delhi - 110002
Ph. : (011) 23242482, 23242483
E-mail: danikabooks@yahoo.com

Terms of Sale

1. © *Copyright Reserved.* No part of this book be reproduced, annotated or translated in any form without written prior permission of the Publishers.
2. The Publishers reserve the right to project the names and photographs of the toppers in media for having used or referred this book or part thereof directly or indirectly.
3. Customer is advised to check the book for missing or defective pages before leaving the book-sellers' counter. In case any defect is reported later for binding, misprint, missing or defective pages etc., The missing or defective pages shall be made available free of charge within the current session only, however, the publishers' liability is limited to the extent of replacement of the defective copy within one month of its purchase by a copy of the same edition or its re-print.

ISBN : 9788187223801

First Edition : 1990
New Edition : 2018

(With Free Booklet)

Price: Rs. 825/-



Trueman's Hologram is guarantee of Original Version. 3D hologram as shown above in artwork is stuck on the cover. The sticker when viewed at a certain angle gives 3D effect of the hologram in multiple colours. 'Original' in the back ground appears differently at a certain depth AND the portrait of SWAMI VIVEKANAND in the fore ground. The back ground appears to move as and when the book is tilted sideways.

Printed at : Dhruv Printers, Delhi

PREFACE

We acknowledge with thanks a very encouraging support from both our fellow teachers and the students for the last many years. This has been the beacon light for us to revise and update our book every year. We feel pleasure to present this revised twenty eighth edition before you.

Every due care has been given while revising this edition. The contents have been prepared and discussed envisaging the guidelines projected by NCERT. Efforts have been made to provide latest material facts with clear concepts.

The Genetics portion constituting Principles of Inheritance and Variations, Molecular Basis of Inheritance and Evolution have been thoroughly revised according to NCERT alongwith many new diagrams added at appropriate places.

The special features of the present edition are :

Solved Value Based Questions have been added at the end of each chapter.

All NCERT based questions have been dealt with explanations in the text.

All the NCERT questions have been answered at the end of each chapter under separate heading.

One and Two Mark Questions have been answered at the end of each chapter.

Special emphasis has been laid to provide latest and useful information on all the topics to make the subject more lucid and understandable for all Boards' and Competitive Examinations.

CBSE and other Boards' Questions upto 2017 and MCQs upto 2017 of various competitive exams have also been inserted in the relevant chapters.

Solved Subjective Exemplar Problems and NCERT Exemplar Questions (Chapter wise) also find place at the end of the book.

We have also maintained the unquestionable reliability of the book as expected by teachers and the taught.

Further suggestions for the improvement of the book are always welcome and shall be thankfully acknowledged.

—Authors

Syllabus — Class XII

& NEET

Unit 1 : Reproduction

- Reproduction in organisms : Reproduction, a characteristic feature of all organisms for continuation of species; Modes of reproduction – Asexual and sexual; Asexual reproduction; Modes– Binary fission, sporulation, budding, gemmule, fragmentation; vegetative propagation in plants.

- Sexual reproduction in flowering plants: Flower structure; Development of male and female– gametophytes; Pollination—types, agencies and examples; Outbreeding devices; Pollen-Pistil interaction; Double fertilization; Post fertilization events – Development of endosperm and embryo, Development of seed and formation of fruit; Special modes– apomixis, parthenocarpy, polyembryony; Significance of seed and fruit formation.

- Human Reproduction : Male and female reproductive systems; Microscopic anatomy of testis and ovary; Gametogenesis-spermatogenesis & oogenesis; Menstrual cycle; Fertilisation, embryo development upto blastocyst formation, implantation; Pregnancy and placenta formation (Elementary idea); Parturition (Elementary idea); Lactation (Elementary idea).

- Reproductive health : Need for reproductive health and prevention of sexually transmitted diseases (STD); Birth control– Need and Methods, Contraception and Medical Termination of Pregnancy (MTP); Amniocentesis; Infertility and assisted reproductive technologies – IVF, ZIFT, GIFT (Elementary idea for general awareness).

Unit 2 : Genetics and Evolution

- Heredity and variation: Mendelian Inheritance; Deviations from Mendelism-Incomplete dominance, Co-dominance, Multiple alleles and Inheritance of blood groups, Pleiotropy; Elementary idea of polygenic inheritance; Chromosome theory of inheritance; Chromosomes and genes; Sex determination—In humans, birds, honey bee; Linkage and crossing over; Sex linked inheritance– Haemophilia, Colour blindness; Mendelian disorders in humans– Thalassaemia; Chromosomal disorders in humans; Down's syndrome, Turner's and Klinefelter's syndromes.

- Molecular basis of Inheritance: Search for genetic material and DNA as genetic material; Structure of DNA and RNA; DNA packaging; DNA replication; Central dogma; Transcription, genetic code, translation; Gene expression and regulation-Lac Operon; Genome and human genome project; DNA finger printing.

- Evolution: Origin of life; Biological evolution and evidences for biological evolution (Paleontological, comparative anatomy, embryology and molecular evidence); Darwin's contribution, Modern Synthetic theory of Evolution; Mechanism of evolution-Variation (Mutation and Recombination) and Natural Selection with examples, types of natural selection; Gene flow and genetic drift; Hardy-Weinberg's principle; Adaptive Radiation; Human evolution.

Unit 3 : Biology and Human Welfare

- Health and Disease; Pathogens; parasites causing human diseases (Malaria, Filariasis, Ascariasis, Typhoid, Pneumonia, common cold, amoebiasis, ring worm); Basic concepts of immunology-vaccines; Cancer, HIV and AIDs; Adolescence, drug and alcohol abuse.

- Improvement in food production; Plant breeding, tissue culture, single cell protein, Biofortification; Apiculture and Animal husbandry.

- Microbes in human welfare : In household food processing, industrial production, sewage treatment, energy generation and as biocontrol agents and biofertilizers.

Unit 4 : Biotechnology and Its Applications

- Principles and process of Biotechnology : Genetic engineering (Recombinant DNA technology).
- Application of Biotechnology in health and agriculture: Human insulin and vaccine production, gene therapy; Genetically modified organisms-Bt crops; Transgenic Animals; Biosafety issues—Biopiracy and patents.

Unit 5 : Ecology and Environment

- Organisms and environment : Habitat and niche; Population and ecological adaptations; Population interactions-mutualism, competition, predation, parasitism; Population attributes—growth, birth rate and death rate, age distribution.
- Ecosystem: Patterns, components; productivity and decomposition; Energy flow; Pyramids of number, biomass, energy; Nutrient cycling (carbon and phosphorous); Ecological succession; Ecological Services-Carbon fixation, pollination, oxygen release.
- Biodiversity and its conservation: Concept of Biodiversity; Patterns of Biodiversity; Importance of Biodiversity; Loss of Biodiversity; Biodiversity conservation; Hotspots, endangered organisms, extinction, Red Data Book, biosphere reserves, National parks and sanctuaries.
- Environmental issues : Air pollution and its control; Water pollution and its control; Agrochemicals and their effects; Solid waste management; Radioactive waste management; Greenhouse effect and global warming; Ozone depletion; Deforestation; Any three case studies as success stories addressing environmental issues. Chikangunya and Dengue.

Theory for Quick Revision

100% Verified Answers

Thoroughly Revised Editions

TRUEMAN'S

Dr. M.P. Tyagi Dr. Arvind Goyal

Objective BIOLOGY

GENERAL
INFORMATION

- Comprehensive Theory
- Systematically arranged MCQs Framed on the basis of the theory of NCERT Book
- Assertion & Reason MCQs
- Solved Exemplary Questions
- Previous Years' Solved Papers

**For
NEET**

TRUEMAN'S

B. L. Taneja

Objective PHYSICS

- Variety of New MCQs
- Complete Hints & Solutions
- Time Saving Techniques

- Previous Years' Solved Papers
- Evaluation Tests
- Verified Answers

TRUEMAN'S

Dr. Rajat Kumar

Objective CHEMISTRY

- Complete Theory Made Easy
- Concept Based MCQs Arranged Systematically
- A Complete package of well crafted Evaluation Tests
- Complete Hints & Solutions
- Previous Years' Solved Papers of AIEEE & CBSE (AIPMT)
- Verified & Reliable Answers

CONTENTS

Unit 1 **REPRODUCTION**

Chapter 1 : REPRODUCTION IN ORGANISMS	U1 - 1
Chapter 2 : SEXUAL REPRODUCTION IN FLOWERING PLANTS	U1 - 39
Chapter 3 : HUMAN REPRODUCTION	U1 - 83
Chapter 4 : REPRODUCTIVE HEALTH	U1 - 140

Unit 2 **GENETICS AND EVOLUTION**

Chapter 5 : PRINCIPLES OF INHERITANCE AND VARIATIONS	U2 - 1
Chapter 6 : MOLECULAR BASIS OF INHERITANCE	U2 - 121
Chapter 7 : EVOLUTION	U2 - 202

Unit 3 **BIOLOGY AND HUMAN WELFARE**

Chapter 8 : HUMAN HEALTH AND DISEASE	U3 - 1
Chapter 9 : STRATEGIES FOR ENHANCEMENT IN FOOD PRODUCTION	U3 - 81
Chapter 10 : MICROBES IN HUMAN WELFARE	U3 - 121

Unit 4 **BIOTECHNOLOGY AND ITS APPLICATIONS**

Chapter 11 : BIOTECHNOLOGY : PRINCIPLES AND PROCESSES	U4 - 1
Chapter 12 : APPLICATIONS OF BIOTECHNOLOGY	U4 - 31

Unit 5 **ECOLOGY AND ENVIRONMENT**

Chapter 13 : ORGANISMS AND POPULATIONS	U5 - 1
Chapter 14 : ECOSYSTEM	U5 - 57
Chapter 15 : BIODIVERSITY AND CONSERVATION	U5 - 103
Chapter 16 : ENVIRONMENTAL ISSUES	U5 - 130

ABBREVIATIONS

AMIS	Antibody Mediated Immune System	MAB	Monoclonal Antibody
AIDS	Acquired Immune Deficiency Syndrome	NFWP	National Family Welfare Programme
ADAM	Androgen Deficiency in Ageing Male	NCP	National Commission on Population
ADA	Adenosine Deaminase	NMR	Nuclear Magnetic Resonance
ATS	Anti-tetanus Serum	NACO	National AIDS- control organisation
ABP	Androgen Binding Protein	Nif-genes	Nitrogen Fixing Genes
BCG	Bacillus Calmette Guerin	NPP	Net Primary Productivity
BOD	Biochemical Oxygen Demand	OPV	Oral Polio Vaccine
bp	Base pair	PEE	Piezo Electric Effect
CFCs	Chlorofluorocarbons	PVS	Potato Virus S
CCC	Convention on Climate Change	ppm	parts per million
CAP	Catabolite activator protein	ppb	parts per billion
COD	Chemical Oxygen Demand	PET	Position emission tomographic scanning
CMIS	Cell Mediated Immune System	PGA	Phosphoglyceric acid
CSIR	Council of Scientific and Industrial Research, New Delhi	PGAL	Phosphoglyceraldehyde
CT Scan	Computed tomography scanning	PID	Pelvic inflammatory disease
CAT	Computerized axial tomography	POST	Peritoneal oocyte and sperm transfer
DDT	Dichloro-diphenyl trichloroethane	PKU	Phenylketonuria
DPT	Diphtherial pertussis tetanus	PAR	Photosynthetically Active Radiation
DMPA	Depot-medroxyprogesterone acetate	pg	Picogram
EEG	Electroencephalogram	Rh	rhesus
ECT	Electro-convulsive therapy	RSV	Rouse sarcoma virus
FAS	Foetal Alcohol Syndrome	RDB	Red Data Book
GnRH	Gonadotropin releasing hormone	Ri	It induces quick rooting in host organism after injection
GIFT	Gamete intra-fallopian transfer	Plasmid	
GMO	Genetically Modified organism	SARS	Severe acute respiratory syndrome
GEM	Genetically Engineered Microorganism	SIFT	Sperm intra Fallopian transfer
HIV	Human immunodeficiency virus	SQUID	Superconducting quantum interference device
HCLV	Human cell leukemia virus	STD	Sexually transmitted disease
hCG	Human chorionic gonadotropin	SCID	Severe combined immunodeficiency disease
HDL	High-density lipoprotein	SV40	Simian Virus 40
HPV	Human papilloma virus	SAFA-test	Solid Antigen Fluorescent Antibody Test- it is a modification of ELISA test
HGP	Human Genome project	Taq	Thermus aquaticus polymerase
HWE	Hardy-Weinberg Equilibrium Principle	Polymerase	
IUD	Intra Uterine Device	TMR	Total metabolic rate
IUCN	International union for the conservation of nature and natural resources	TMV	Tobacco mosaic virus
ICSI	Intra-cytoplasmic sperm injection	TFR	Total fertility rate
IPM	Integrated Pest Mangement	TPA	Tissue Plasminogen Activator
IUI	Intra-uterine Insemination	T-i	Tumour inducing plasmid
Kbp	Kilobase pair	Plasmid	
LASER	Light amplification by stimulated emission of radiation	UNEP	United Nations Environment Programme
LDL	Low-density lipoprotein	UNDP	United Nations Development Programme
LSD	Lyseric acid diethylamide	UNCED	United Nations Conference on Environment and Development
MOET	Multiple ovulation Embryo Tansfer	VLDL	Very low-density lipoprotein
MAB	Man and Biosphere Programme	WCP	World Climate Programme
MET	Magnetoencephalography	WPSI	Wildlife Preservation Society of India
MRI	Magnetic resonance imaging	WWF	World Wildlife Fund
MESA	Microsurgical epididymal sperm aspiration	WFN	World Wildlife Fund for Nature
MALT	Mucosal Associated Lymphoid Tissues	WCU	World Conservation Union
MMR	Mumps, Measles and Rubella vaccine	WHO	World Health organisation
		ZIFT	Zygote Intra-Fallopian Transfer



REPRODUCTION IN ORGANISMS

Reproduction is one of the fundamental characteristics of living organisms. It involves the formation of young ones by the grown up individuals. This helps in perpetuation of species.

LIFE SPAN

The period from birth to the natural death of an organism is called its **life span**. Life span of an organism may be few minutes to several thousand years. Life span of Mayfly is one day, while giant tortoise is considered the longest living animal (about 100 to 150 years).

Life Spans of some living beings

Organism	Maximum Life-span	Organism	Maximum Life-span
1. Some microorganisms	Few minutes to few hours	16. Cat	35-40 years
2. May fly	1 day	17. Whale	37 years
3. Cicada	1 day	18. Horse	50 years
4. Butterfly	1-2 weeks	19. Crocodile	60 years
5. Fruit fly	1 month	20. Elephant	60-75 years
6. Rice plant	4 months	21. Eagle	90 years
7. Wheat plant	5 months	22. Man	100 years
8. Rat	4 years	23. Parrot	140 years
9. Rose Bush	10 years	24. Tortoise	100-150 years
10. Rabbit	13 years	25. Banyan Tree	200-300 years
11. Crow	15 years	26. Peepal	2000-3000 yrs
12. Cow	25 years	27. Sequoia	3000-4000 yrs
13. Banana Tree	25 years	(Red Wood Tree)	
14. Monkey	26 years	28. <i>Larrea tridentata</i> . (Oldest plant found in S.W. California U.S.A.)	
15. Dog	25 years		11,300 years

Life span of an organism usually includes four stages : (i) **Juvenility**. During this stage organism develops the capacity to reproduce. (ii) **Maturity**. Reproduction begins during this stage. (iii) **Ageing and Senescence**. Ageing is progressive deterioration in the body of the organisms. The terminal irreversible stage of ageing is called senescence. (iv) **Death**. Senescence finally leads to death. During this stage there is final permanent cessation of all vital activities of an organism. The change over from one stage to another is determined by genetic as well as environmental factors.

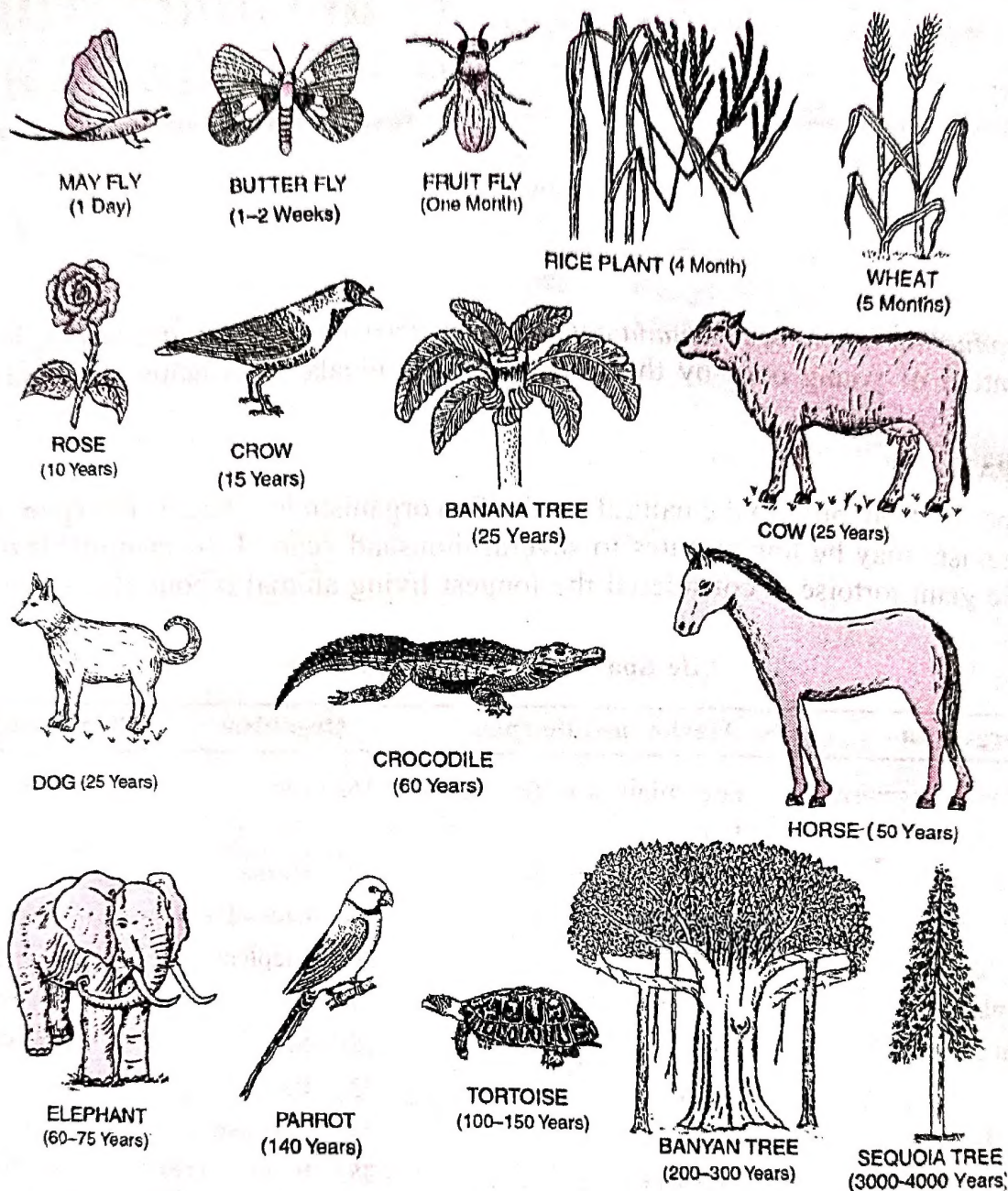


Fig. 1.1. Approximate life spans of some organisms.

It is not essential that life span of organisms should be correlated with their sizes. For example, the sizes of crows and parrots are not very different but their life spans show great difference. In another example, a mango tree has a much shorter life span as compared to a peepal tree. Whatever is the life span, death of every organism is must. It means no individual is immortal except some single-celled (e.g., *Amoeba*) organisms which divide to form two individuals before becoming old.

What is Reproduction ?

Reproduction is a biological process in which organisms produce young ones (offspring) similar to themselves. The young ones grow and mature to repeat the process. Reproduction is one of the most important characteristics of the living organisms.

Purpose of Reproduction

1. **Continuity of Species.** Reproduction maintains the continuity of species.
2. **Population Organisation.** Reproduction maintains population of the young, adult and the aged persons.
3. **Variations.** Reproduction introduces variations in the organisms. Useful variations are essential for adaptations and evolution.
4. **Life.** Life exists on earth due to reproduction in organisms.

Basic Features of Reproduction

All modes of reproduction have some common basic features. These are as follows : (i) Synthesis of RNA, proteins and other biochemicals. (ii) Replication of DNA. (iii) Cell division. (iv) Growth of cells. (v) Formation of reproductive units. (vi) Formation of new individuals from reproductive units.

Types of Reproduction

Mode of reproduction depends upon the structural complexity, physiology and habitat of the organisms. It is of two main types, **asexual** and **sexual**.

ASEXUAL REPRODUCTION

When offspring are produced by a single parent without the involvement of gametic fusion, the reproduction is called **asexual**. As a result, the offspring that are produced are not only similar to one another but are also exact copies of their parent. Such a group of morphologically and genetically similar individuals is called **clone**.

Characteristics of Asexual Reproduction

(i) A single parent is involved (uniparental condition). (ii) Gametes are not formed. (iii) No fertilization. Therefore, asexual reproduction is also called **agamogenesis** or **agamogeny**. (iv) There is only mitotic cell division. Asexual reproduction is hence **somatogenic reproduction**. (v) Daughter organisms are genetically identical to parent. (vi) Multiplication occurs rapidly.

Occurrence

Asexual reproduction occurs in unicellular organisms, (Monerans and Protists), many plants and simple animals. It is absent in vertebrates and higher invertebrates.

Types of Asexual Reproduction

~ Asexual reproduction takes place in the following ways.

I. Fission (*L. fissus* — cleft)

This is the division of the parent body into two or more daughter individuals identical to the parent. Fission can occur by binary fission, multiple fission and plasmotomy.

1. **Binary Fission.** In this process of asexual reproduction, the parent organism divides into two halves, each half forming an independent daughter organism. Binary fission involves mitosis. The resultant offspring (pl. offspring) are genetically identical to the parent and to each other. Depending upon the plane of division, binary fission is of the following types.

(i) **Simple Binary Fission** (Irregular Binary Fission). It can occur through any plane, e.g., *Amoeba*.

(ii) **Longitudinal Binary Fission.** The plane of division passes along the longitudinal

axis of the organism. It occurs in flagellates such as *Euglena*. The flagellum divides first followed by body.

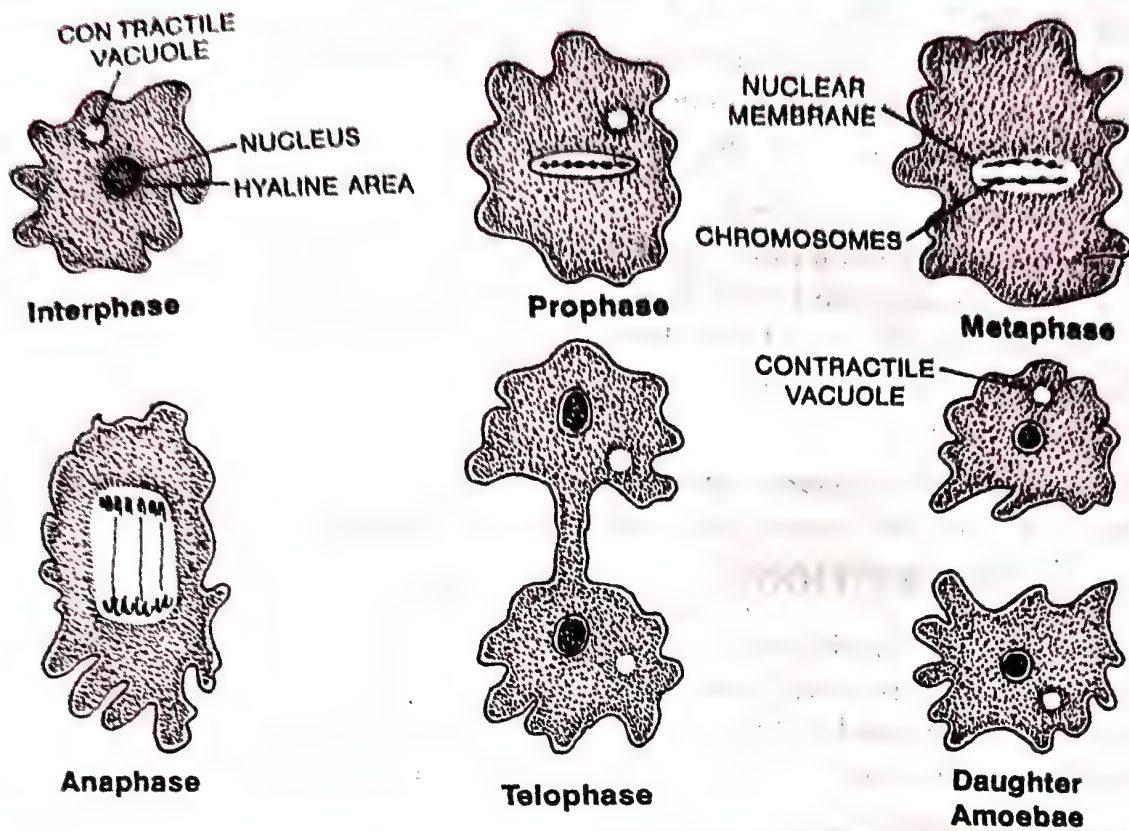


Fig. 1.2. Irregular Binary Fission in *Amoeba*.

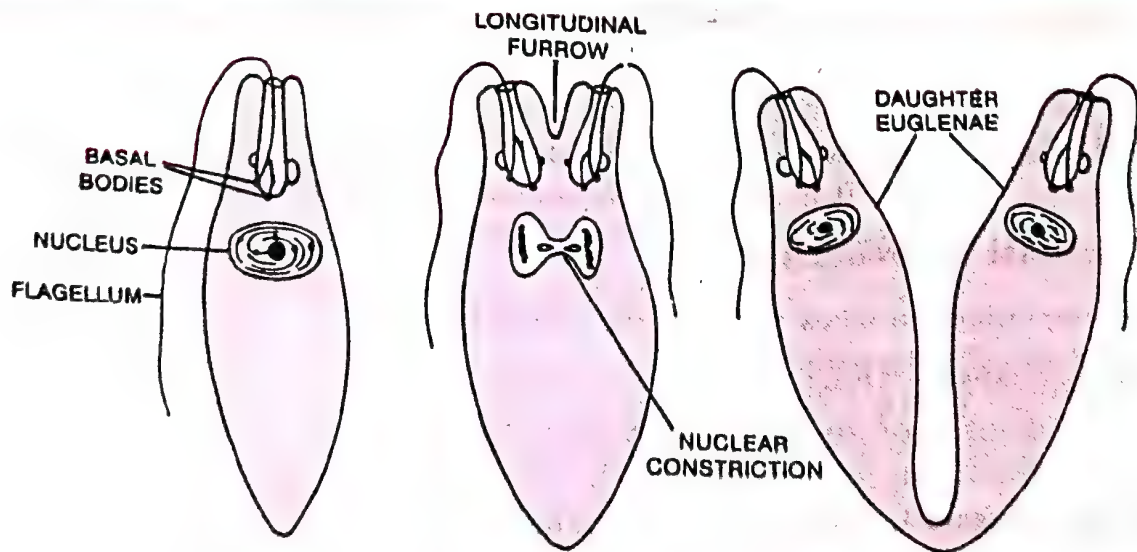
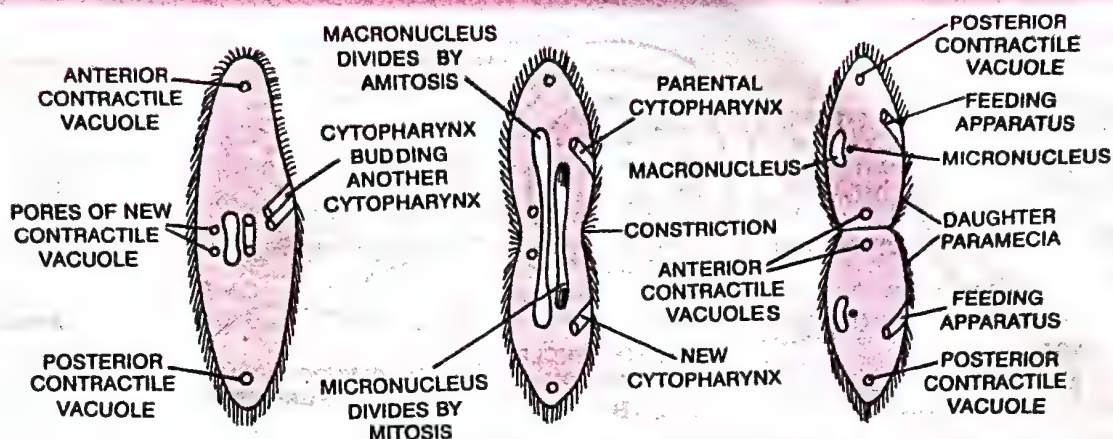
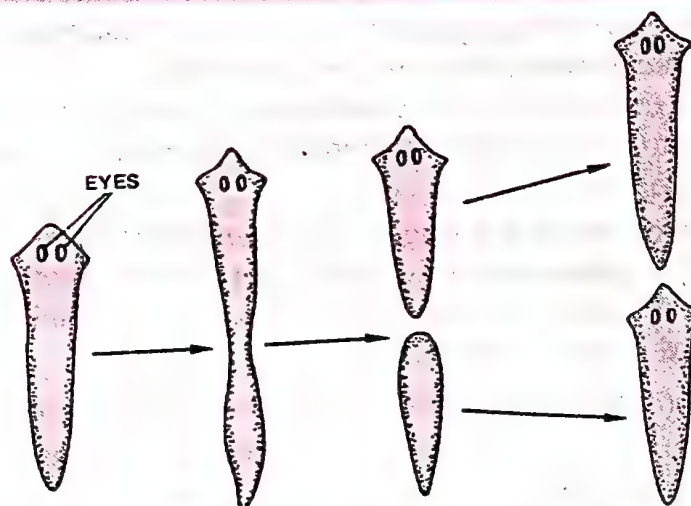


Fig. 1.3. Longitudinal Binary Fission in *Euglena*.

(iii) **Transverse Binary Fission.** The plane of division runs along the transverse axis of the individual, e.g., *Paramecium*, *Planaria*, diatoms and bacteria. In *Paramecium* the meganucleus divides by amitosis, while micronucleus divides by mitosis.

Fig. 1.4. Transverse Binary Fission in *Paramecium*.Fig. 1.5. Transverse Binary Fission in *Planaria*.

(iv) **Oblique Binary Fission.** The plane of division is oblique. It occurs in dinoflagellates, e.g., *Ceratium*.

Reproductive Unit and Immortality

In binary fission, the parent body as a whole forms the reproductive unit and disappears after its division into daughter individuals. Therefore, the parent can not be said to have died. In fact, the parent continues living as two daughter individuals. Thus the organisms that undergo binary fission are said to be immortal.

2. Multiple Fission. In this process the parent body divides into many similar daughter individuals.

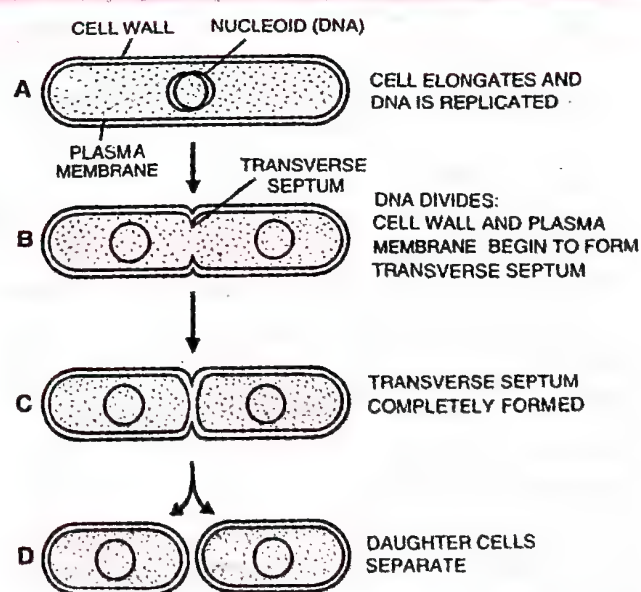
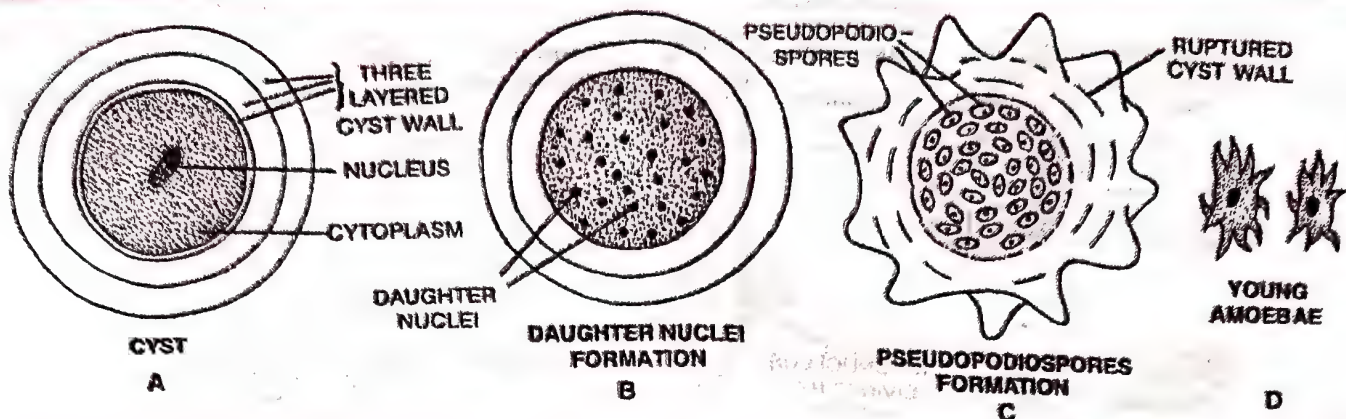
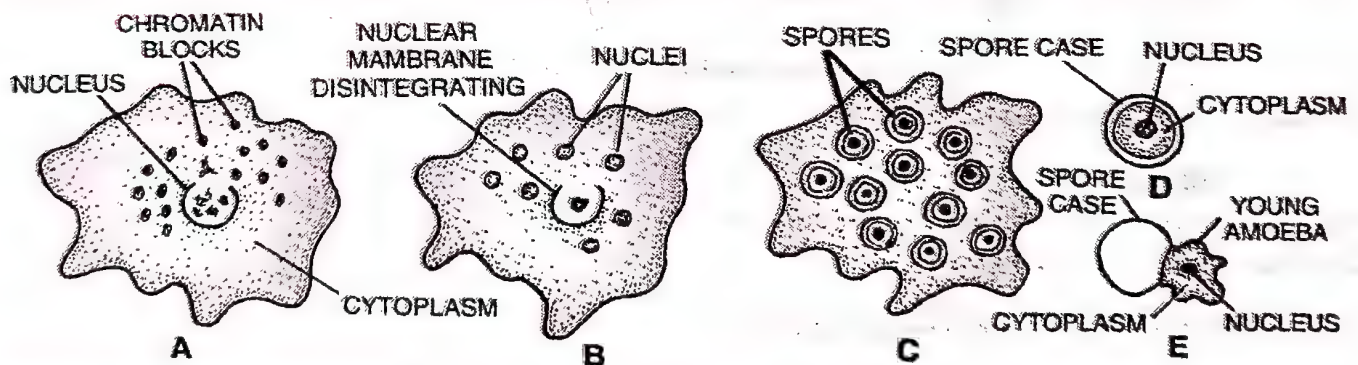


Fig. 1.6. Binary fission in bacteria.

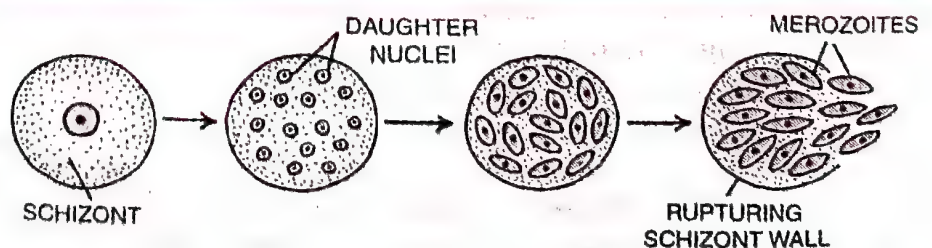
Fig. 1.7. Multiple fission in encysted *Amoeba*.

(i) **Multiple Fission in *Amoeba***. Under unfavourable conditions, *Amoeba*, withdraws its pseudopodia and secretes a three layered thick covering—the **cyst wall** around itself. This phenomenon is called **encystation**. On return of favourable conditions the encysted *Amoeba* divides by multiple fission and produces many minute amoebae called **pseudopodiospores**. The cyst wall ruptures to release the pseudopodiospores in the surrounding medium. They grow up into mature amoebae.

Sometimes instead of forming a single cyst *Amoeba* produces a number of **spores** or ensheathed amoebae. The phenomenon is called **sporulation**. Spores take part in both dispersal and perennation (passing through unfavourable period). Under favourable conditions each spore gives rise to a small *Amoeba*.

Fig. 1.8. Multiple Fission in uncysted *Amoeba*.

(ii) **Multiple Fission in *Plasmodium* (Malarial Parasite)**. In *Plasmodium* multiple fission occurs in the **schizont** (rounded unicellular structure present in liver cell and RBC of the man) as well as **oocyst** (encysted zygote) present over the stomach of female *Anopheles*. When multiple fission occurs in schizont, the process is called **schizogony** and the daughter individuals are

Fig. 1.9. Multiple Fission in *Plasmodium*.

called **merozoites**. The process of multiple fission in oocyst is termed **sporogony** and the daughter individuals are known as **sporozoites**.

Multiple fission is also found in *Monocystis* — also a protozoan.

3. **Plasmotomy**. It is the division of a multinucleate parent into many multinucleate daughter individuals without division of nuclei. Nuclear division occurs later on to maintain normal number of nuclei. Plasmotomy occurs in *Opalina* and *Pelomyxa* (Giant Amoeba). Both *Opalina* and *Pelomyxa* are protozoans.

Differences between Binary Fission and Multiple Fission

Binary Fission	Multiple Fission
1. It forms two daughter individuals.	1. It produces a number of daughter individuals.
2. The nucleus of the parent body divides only once.	2. The nucleus of the parent body divides repeatedly.
3. In binary fission, no residue is left.	3. In multiple fission a residue is often left behind.
4. It occurs during favourable condition.	4. It can take place under favourable conditions (e.g., <i>Plasmodium</i>) as well as unfavourable conditions (e.g., <i>Amoeba</i>).
5. Binary fission makes the organism immortal. Examples : Bacteria, <i>Amoeba</i> , <i>Euglena</i> , <i>Paramecium</i> , <i>Planaria</i> .	5. Immortality is absent in multiple fission. Example : <i>Amoeba</i> , <i>Plasmodium</i> .

II. Budding

In budding, a daughter individual is formed from a small part or **bud**, arising from parent body.

(i) **Budding in Yeast**. In yeast, an outgrowth develops on one side of the cell. Nucleus divides mitotically and one nucleus shifts into the outgrowth now called **bud**. There is unequal division during budding. The young bud is small. It grows in size, gets separated and matures into new yeast organism. Sometimes, yeast may bear many buds which may further bear daughter buds. This budding stage in yeast resembles with a genus *Torula*. Therefore, this condition is called **torula** stage and the process is known as **torulation**.

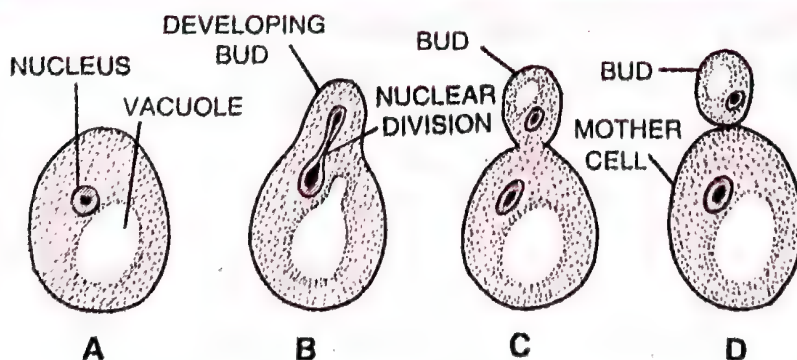


Fig. 1.10. Budding in yeast.

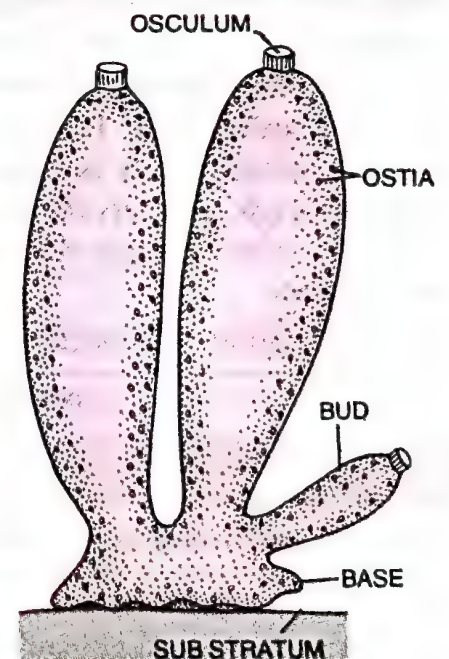
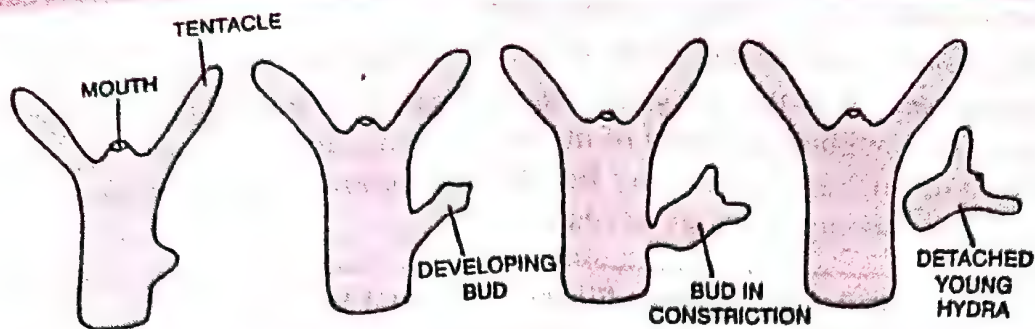


Fig. 1.11. External Budding in Sycon (*Scypha*).

Fig. 1.12. Budding in *Hydra*.

(ii) **Budding in Animals.** It is of two types :

(a) **Exogenous/External Budding.** In this type of budding an outgrowth or bud grows externally on the surface of the body. The bud may split away from the parent and take up an independent existence as in *Hydra* or it may remain attached and become a more or less independent member of the colony as in *Sycon*. Exogenous budding also occurs in certain annelids (*Syllis*) and urochordates or tunicates (*Salpa*).

(b) **Endogenous/Internal Budding (Gemmule Formation; Fig. 1.13).** In the fresh water sponges (e.g., *Spongilla*) and a few marine sponges buds are formed within the parent's body. They are called **gemmules** (= internal buds). Gemmules consist of small groups of cells (archaeocytes) enclosed by a protective coat. During favourable conditions the mass of archaeocytes comes out through **micropyle** and forms a new colony.

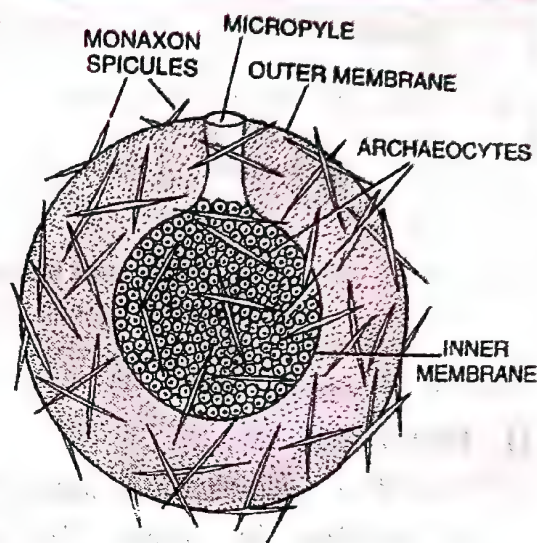


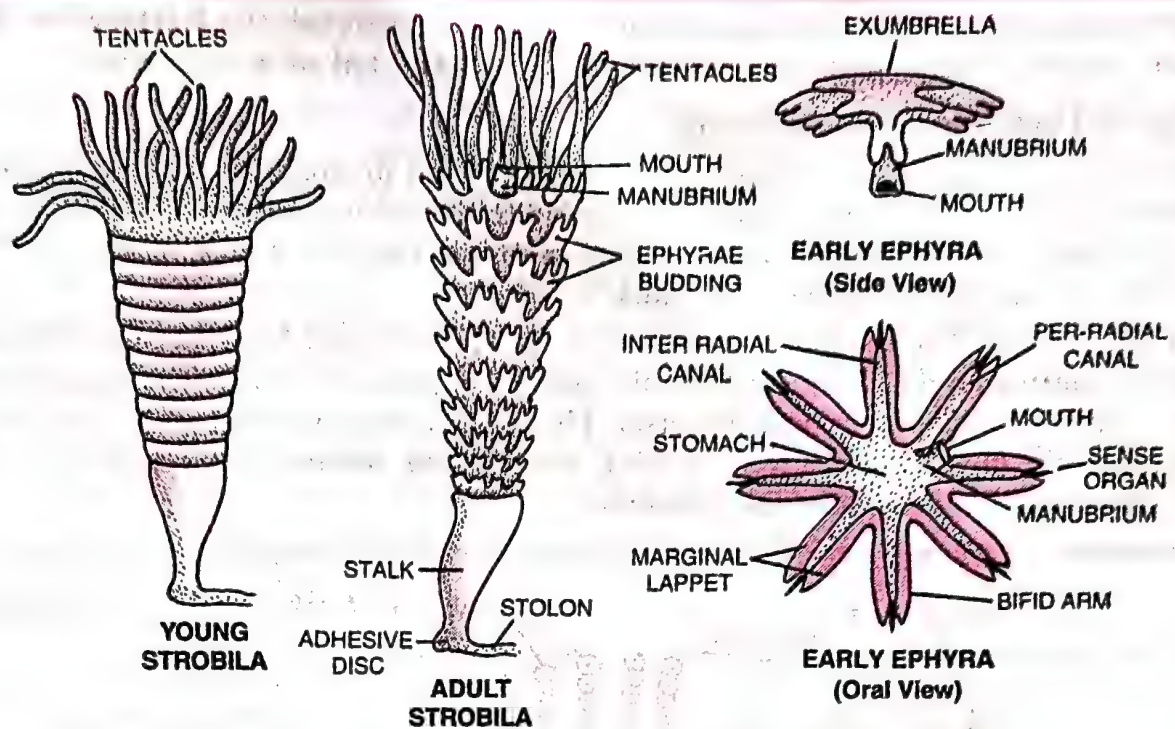
Fig. 1.13. Gemmule

(c) **Strobilation.** The repeated formation of similar segments by a process of budding is called strobilation. The segmented body is called a **strobila** (= *Scyphistoma*) larva and each of the segments is called an **ephyra** larva as found in *Aurelia* (a coelenterate). The ephyrae break at intervals and swim in the water. The free ephyrae feed, grow and in due course of time change into jelly fishes. About a dozen ephyrae are formed in a single strobilation.

Strobilation also occurs in the neck of *Taenia* (Tapeworm).

Differences between Binary Fission and Budding

Binary Fission	Budding
<ol style="list-style-type: none"> 1. The parent body divides into two equal and similar halves. Each half forms a new individual. 2. A protuberance is not formed. 3. Division is equal. 4. Parent body disappears. <p>Examples : <i>Bacteria</i>, <i>Amoeba</i>, <i>Euglena</i>, <i>Paramecium</i>, <i>Planaria</i>.</p>	<ol style="list-style-type: none"> 1. The parent produces a small bud that gradually grows in size and then separates from the parent body. 2. A protuberance (bud) is formed. 3. Division is unequal. 4. Parent body remains intact. <p>Example : <i>Yeast</i>, <i>Sycon</i>, <i>Hydra</i>.</p>

Fig. 1.14. Strobilation in *Aurelia*.

III. Fragmentation

The parent body breaks into two or more pieces called fragments. Each fragment develops into an individual. It is found in sponges, sea anemones (coelenterates) and echinoderms. In a starfish, one arm with a part of central disc can develop into a starfish.

Fragmentation is also found in algae (e.g., *Spirogyra*), fungi (e.g., *Rhizopus*), bryophytes (e.g., *Riccia*, *Marchantia*), pteridophytes (e.g., *Selaginella rupestris*), etc.

IV. Gemmae

They are unicellular or multicellular propagules that detach from the parent and grow into new individuals. In *Marchantia* (Fig. 1.28 D) gemmae are biscuit shaped multicellular green structures which are borne in small cup-shaped outgrowths called gemma cups. The mature gemmae detach in presence of water and float to reach new substratum for formation of new thalli. The gemmae formed by the male thallus produce male thalli while those of the female thallus develop into female thalli.

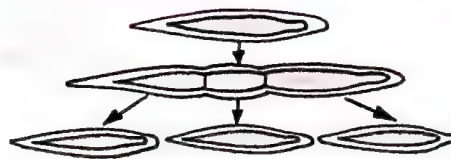


Fig. 1.15. Fragmentation in a flatworm.

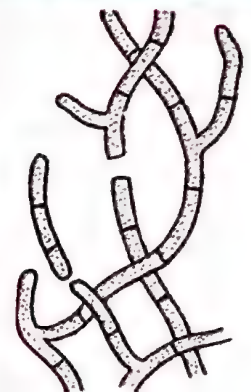


Fig. 1.16. Fragmentation in fungus.

V. Regeneration

Regeneration is the regrowth in the injured region. Regeneration is of two types, morphallaxis and epimorphosis. In **morphallaxis** the whole body grows from a small fragment. It is a type of asexual reproduction as found in Sponges, *Hydra*, *Planaria*, etc. Regeneration was first discovered in *Hydra* by Abraham Trembley in 1740.

Epimorphosis is the replacement of lost body parts. It is of two types : (i) **Reparative Regeneration**. Only certain damaged tissues can be regenerated. (ii) **Restorative Regeneration**. Severed body parts can redevelop, e.g., broken tail of wall Lizard.

VI. Spore Formation (Sporulation)

Spores are minute, single celled, thin or thick walled **propagules**. They are dispersive structures which also form new individuals. Spore formation is common in monera, protista, algae and fungi. Motile spores are called **zoospores**. The non-motile spores are named variously such as sporangiospores, conidia, etc.

(i) **Zoospores**. The zoospores are special kind of motile and flagellate spores produced inside the **zoosporangia**. They are generally naked (without cell wall). The flagella help to swim in aquatic habitat for proper dispersal. The reproduction by zoospores occurs in some lower fungi like phycomycetes (e.g., *Achlya*, *Saprolegnia*, *Albugo*, *Phytophthora*, etc.) and many algae (e.g., *Chlamydomonas*, *Ulothrix*).

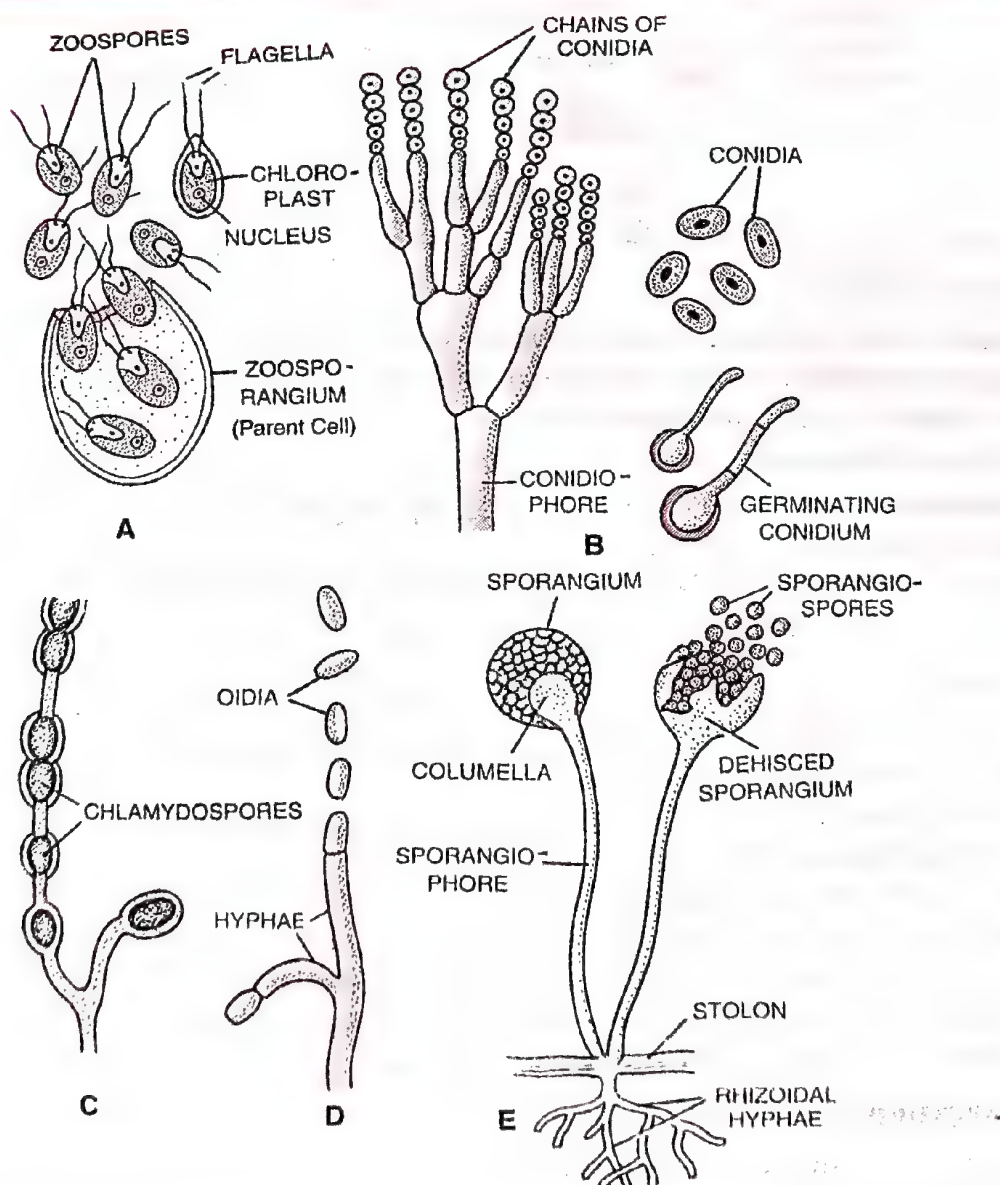


Fig. 1.17. Various types of spores. (A) Zoospores, (B) Conidia, (C) Chlamydospores, (D) Oidia, (E) Sporangiospores.

(ii) **Conidia.** They are formed in *Pencillium* and other ascomycetes. Conidia are non-motile spores produced singly or in chains by constriction at the tip of special hyphal branches, called **conidiophores**. They are produced exogenously.

(iii) **Chlamydospores.** They are **thick-walled** spores produced directly from hyphal cells. They may be terminal or intercalary. They store reserve food material and are capable of withstanding long unfavourable conditions. Chlamydospores are formed in *Rhizopus*, *Agaricus* (mushroom), etc.

(iv) **Oidia.** In some fungi (e.g., *Agaricus*) the hyphae break up into numerous small thin walled fragments known as **oidia**. They are generally formed under conditions of excess water, sugar and certain salts. Oidia can multiply by budding. On solid substratum they give rise to new hyphae.

(v) **Sporangiospores.** They are non-motile spores produced inside the sporangia. Sporangiospores are also called **endospores**. They are generally dispersed by wind and germinate to produce new mycelium (e.g., *Rhizopus*, *Mucor*).

VII. Vegetative Propagation

Vegetative propagation (vegetative reproduction) is the formation of new plants from vegetative units or propagules such as buds, tubers, rhizomes, etc. This method produces a large number of population of clones in shortest time. It preserves purity, resistance and good qualities of race/variety indefinitely. Vegetative propagation is of two types, natural and horticultural (= artificial).

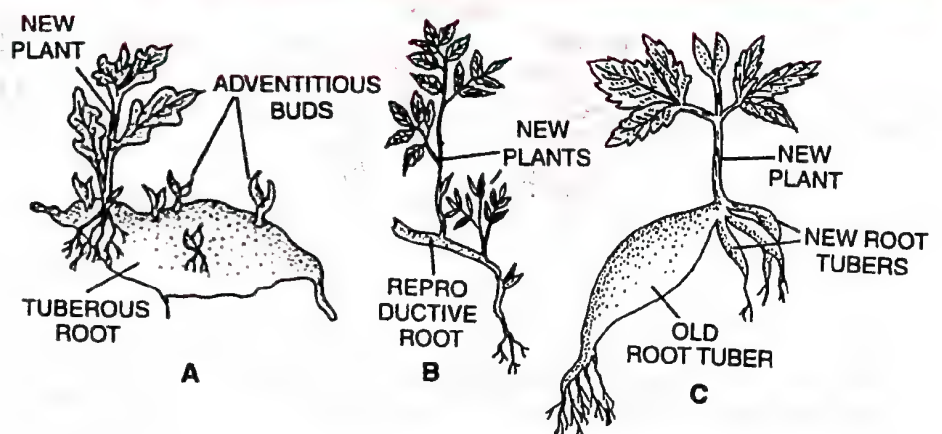


Fig. 1.18. A–C. Vegetative reproduction by roots. A, Adventitious buds growing into new shoots in tuberous root of Sweet potato. B, Young shoots arising from reproductive root of *Dalbergia* (Sheesham). C, Old root tuber of *Dahlia* growing into new plant.

A. Natural Methods of Vegetative Propagation

In these methods, vegetative propagules (somatic parts) of the plant detach from the body of the mother and develop into new plants under suitable conditions. It is done by following means :

(1) **Roots.** Both tap roots and adventitious roots take part in vegetative propagation. Tap roots of some plants develop adventitious buds to form new plants, e.g., *Dalbergia* (Sheesham), Guava, Poplar, *Albizia*, *Murraya*. Fleshy roots (root tubers) which develop adventitious buds also take part in vegetative propagation, e.g., Sweet Potato, Tapioca, *Dahlia*, *Asparagus*.

(2) **Underground Stems.** Different types of underground stem structures can take part in vegetative propagation. (Fig. 1.19)

(i) **Tubers.** These have buds over their nodes or eyes. The buds produce new plantlets when a stem tuber or a part of it having an eye is placed in the soil, e.g., Artichoke, Potato.

(ii) **Bulbs.** Bulbs are underground condensed shoots which have one or more buds. These buds present inside the bulbs form new plants, e.g., Garlic, *Narcissus*, Onion.

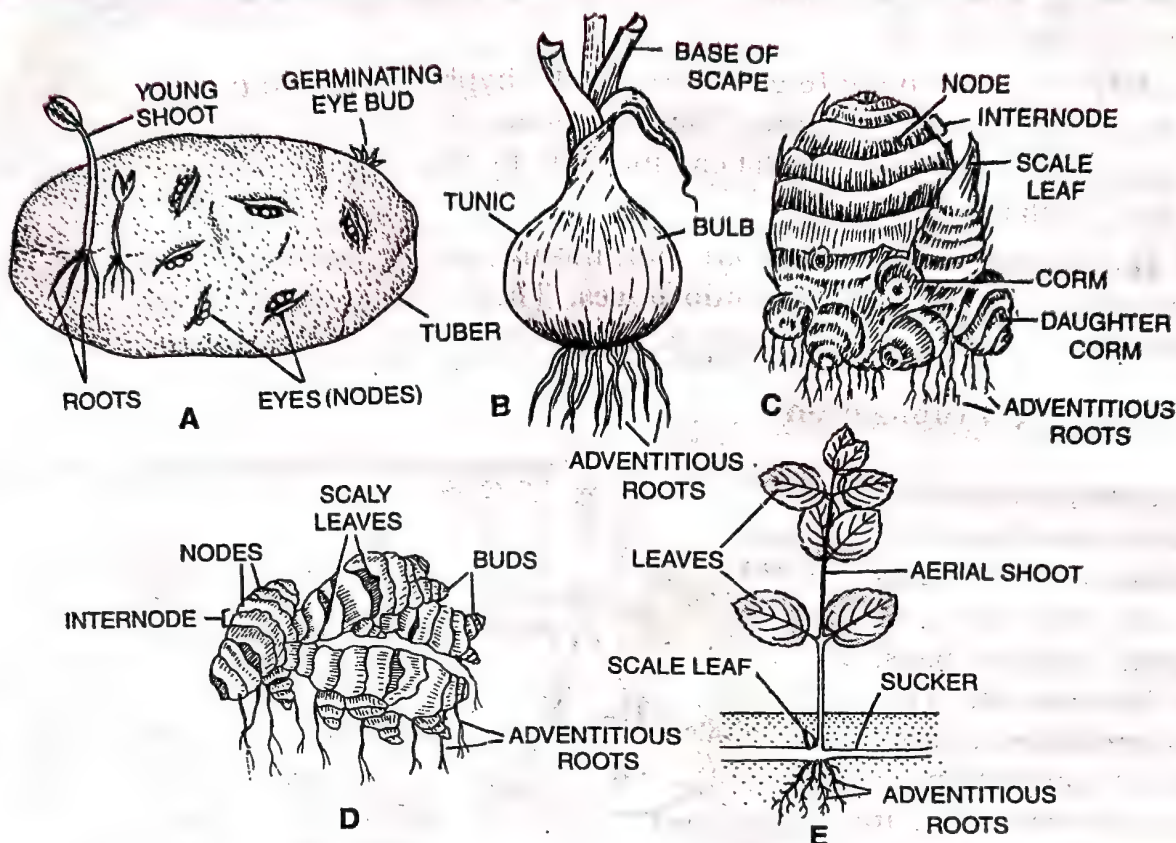


Fig. 1.19. A. Young shoots arising from the buds in the regions of node (eye) in stem tuber of potato. B. Tunicated bulb of onion. C. Corm of *Colocasia*. D. Rhizome of Ginger. E. Sucker of Mint (*Podina*).

(iii) **Corms.** These are unbranched swollen underground stems having circular nodes that have buds for growth of daughter plants, e.g., *Amorphophallus* (Zamikand), *Colocasia*, *Crocus*, *Fressia*.

(iv) **Rhizomes.** Rhizomes are main underground stems which store food for perennation during unfavourable conditions. These have buds for formation of new aerial shoots during favourable conditions. Rhizomes take part in vegetative propagation due to these buds, e.g., Banana, Ginger, Turmeric, *Aspidium*, *Adiantum*.

(v) **Suckers.** These are slender underground branches that develop from base of aerial shoot, grow for some distance and form new aerial shoots or crowns. Breaking of suckers forms new plants, e.g., Mint, *Chrysanthemum*.

(3) **Subaerial or Creeping Stems.** They are of three types — runners, stolons, offsets (Fig. 1.20).

(i) **Runners.** These are narrow, green, horizontal branches which develop at the base of crown and root at intervals where new crowns are also formed. Breaking of runners helps in vegetative propagation, e.g., Lawn Grass or *Cynodon* (= Doob grass), *Centella*, *Oxalis* (wood-sorrel).

(ii) **Stolons.** These are arched horizontal branches that develop at the base of a crown and help in vegetative propagation like runners, e.g., Strawberry, *Vallisneria*.

(iii) **Offsets.** These are one internode long runners that occur in some aquatic plants. Breaking of offsets helps in propagation, e.g., *Eichhornia* (Water Hyacinth), *Pistia* (Water Lettuce).

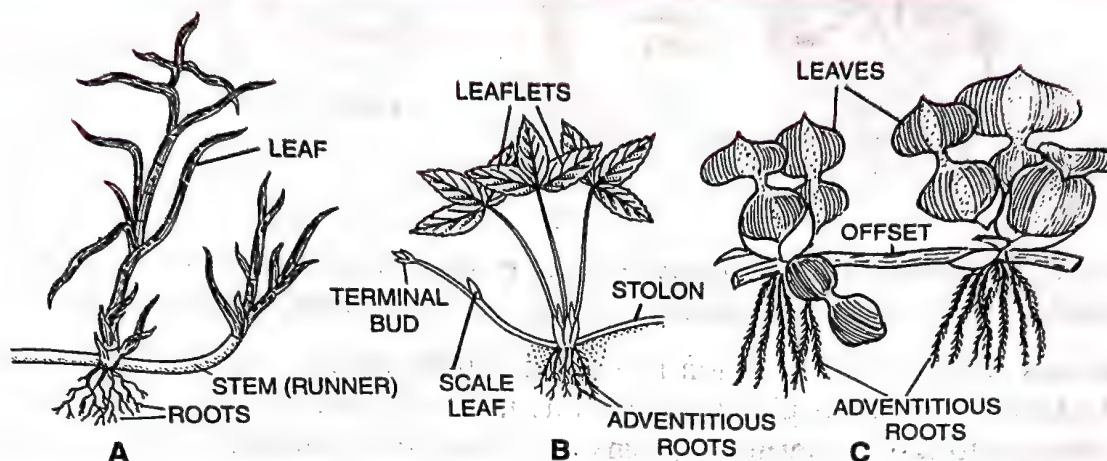


Fig. 1.20. A, Runner of Grass. B, Stolon of wild Strawberry. C, Offset of Water hyacinth.

(4) **Aerial Stems (Aerial Shoots Fig. 1.21).** Fleshy phylloclades occur in *Opuntia* and some other plants. Each segment of such stems can form a new plant. Sugarcane is propagated by planting segments of stems having at least one node.

(5) **Leaves (Fig. 1.22A).** Leaves of many plants have adventitious buds and help in vegetative propagation, e.g., *Begonia*, *Bryophyllum*, *Kalanchoe*, *Streptocarpus*, *Saintpaulia*, *Adiantum caudatum*. In *Begonia*, injured leaf develops into new plants. Uninjured fallen *Bryophyllum* leaf does so from buds present in its marginal notches. In *Bryophyllum daigremontianum* buds on marginal notches of intact leaves form plantlets while attached to plants. *Adiantum caudatum* is called **Walking Fern** because its leaf tips form new plants when they come in contact with soil.

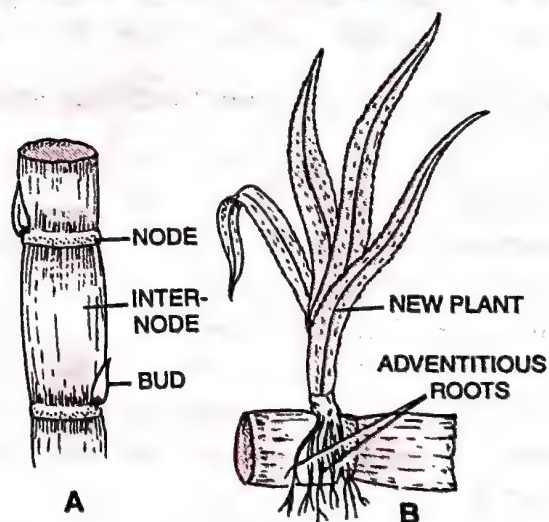


Fig. 1.21. A, a portion of sugarcane stem having buds. B, a bud growing into new plant.

(6) **Bulbils (Fig. 1.22B).** These are multicellular fleshy buds that take part in vegetative propagation, e.g., *Oxalis*, *Agave*, Pineapple (Ananas), *Dioscorea* (Yam), Lily, *Chlorophytum*. In *Agave*, bulbils are modified floral buds that develop on the flowering axis. They remain attached to floral axis and germinate. Thus *Agave* (century plant) shows vegetative reproduction from reproductive organ like floral buds. Bulbils are axillary in *Dioscorea*. In *Oxalis* they are borne over the base of fleshy root.

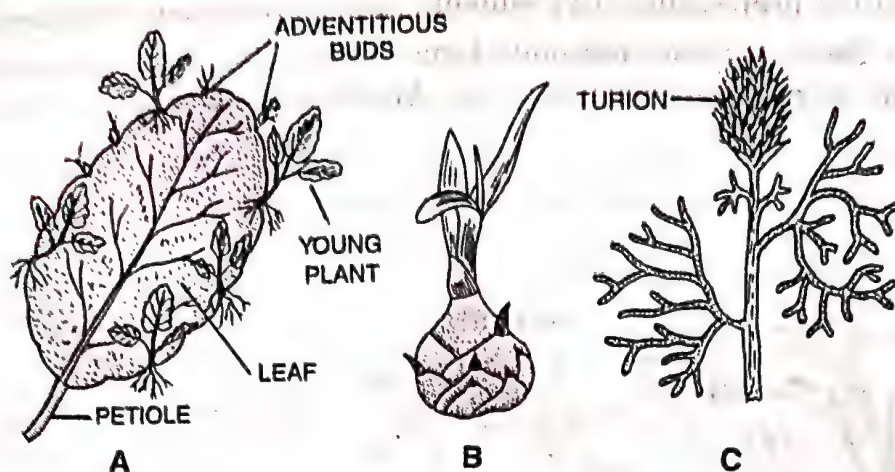


Fig. 1.22. A, leaf buds of *Bryophyllum*. B, Bulbil of *Agave*. C, *Utricularia* showing turion.

(7) **Turions** (Fig. 1.22C). A turion is a swollen bud, which contains much stored food. It is detached from the parent plant and remains inactive through the winter and gives rise to a new plant in following spring. Turions are found in a number of water plants, (e.g., *Potamogeton*, *Utricularia*, etc.)

Water hyacinth or “terror of Bengal” (Fig. 1.20C) is the aquatic plant which is one of the most invading weeds found growing in the standing water. It takes oxygen from the water which causes death of fishes. This plant was introduced into India for its beautiful flowers and shape of leaves. It can propagate vegetatively at a fast rate and spread all over the water body in short time. It is very difficult to remove it from the water body.

B. Horticultural or Artificial Methods of Vegetative Propagation

They are methods of vegetative propagation developed by horticulturists to quickly multiply desired varieties of plants from parts of their somatic body. Some of the artificial methods of vegetative propagation are given below :

(1) **Cuttings**. Cuttings are cut pieces of root, stem and leaves which are planted in nurseries. For this, root promoting chemicals are used, e.g., IBA (Indole-butyric acid), NAA (Naphthalene acetic acid).

(i) **Root Cuttings**. These are pieces of roots which are used to artificially propagate new plants. Root cuttings are used in propagation of Lemon, Orange, Blackberry, Boysenberry, Raspberry, etc.

(ii) **Stem Cuttings**. It is a common method of plant propagation. 20–30 cm long pieces of one year old stems are cut. Their lower ends are dipped in root promoting hormones for several minutes before planting in the soil. Some examples are Rose, Sugarcane, *Duranta*, *Citrus*, Grape, Coffee, *Clerodendron*, Tea, *Bougainvillea*, *Croton*, China Rose, *Carnation*, *Tapioca*.

(iii) **Leaf Cuttings**. Snake Plant (*Sansevieria*) and *Saintpaulia* can be propagated by leaf cuttings. Leaves are cut transversely into two or three parts and planted in vertical position in the soil.

(2) **Layering (Soil Layering)**. It is a type of rooting-cutting in which adventitious roots

*Horticulture — Cultivation of flowers, fruits and vegetables intensively.

are induced to develop on a soft stem while it is still attached to the plant. Layering is carried out on one year old basal branches commonly during early spring or early rainy season. A soft basal branch is defoliated in the middle where a small injury or cut is given—tongueing (oblique cut), notching (V-shaped cut), ringing (removal of ring of a bark). The injured defoliated part is pegged in the soil to develop adventitious roots. The pegged down branch of the plant is called **layer**. Later on as the roots develop, the layer is separated and planted. Layering is of following kinds :

(i) **Mound Layering** (Fig. 1.23). The shoot is pruned and lower part is covered by soil, like a mound. A number of new shoots develop. Rooted shoots are separated and planted, e.g., Apple, Pear, Quince, Currant, Gooseberry, Jasmine, Grapevine, Strawberry, Raspberry, Cherry, etc.

(ii) **Gootee or Air Layering** (Fig. 1.24). It is an ancient technique of propagation of tropical and subtropical trees and shrubs. During early monsoon rains 3–5 cm long ring of bark is removed from basal region of a healthy and woody branch. It is covered by a thick plaster of **grafting clay**. Grafting clay is composed of 1 part cowdung, 1 part finely cut hay or moss and two parts clay. To it water is added alongwith a small quantity of root promoting hormones like IAA (Indole acetic acid), IBA or NAA. It is then wrapped in polythene. After 2–3 months, root appear. The shoot is now cut below the bandage and used for planting, e.g., Litchi, Pomegranate, China Rose, Guava, Orange, Lemon.

(iii) **Simple Layering**. In this layering, soft basal partly injured branch is pegged at one place, e.g., Cherry, Jasmine, Grape Vine.

(iv) **Serpentine Layering**. Branch is pegged at several places so as to form many plants, e.g., *Clematis*.

(v) **Trench Layering**. The branch is pegged in a horizontal position in a trench. It develops a number of vertical shoots, e.g., Walnut, Mulberry.

(3) **Grafting** (Fig. 1.25). Grafting is a technique of connecting two parts, usually a root system and a shoot system of two different plants in such a way that they unite and later develop as a **composite plant**. It is physical and physiological joining of separate individuals. It is used only in cambium containing woody eustelic plants. A small shoot of plant with superior characters is employed as **graft** or **scion**. It should have one to several buds. The root system of the other plant which is disease resistant and has good root system is used as **stock** (rootstock, understock). The shoot of the stock is cut 10–30 cm above the base of the root. Stock and scion are attached, union area covered with grafting wax and bandaged in such a way that they fit into each other and their cambia come in contact. Callus is formed. It helps in their fusion. Grafting is not successful in monocots as they do not have cambia.

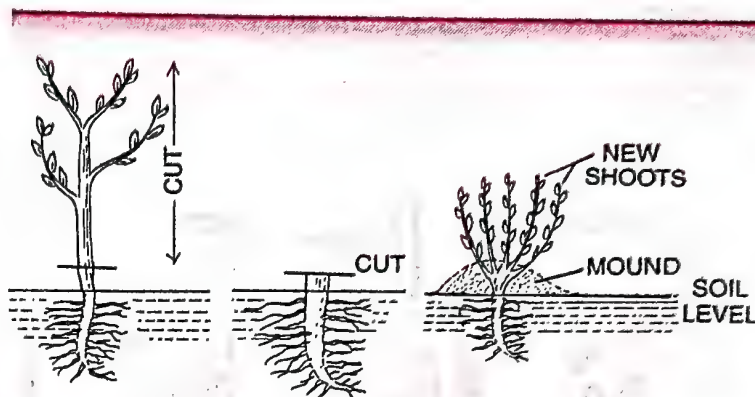


Fig. 1.23. Stages in Mound Layering.

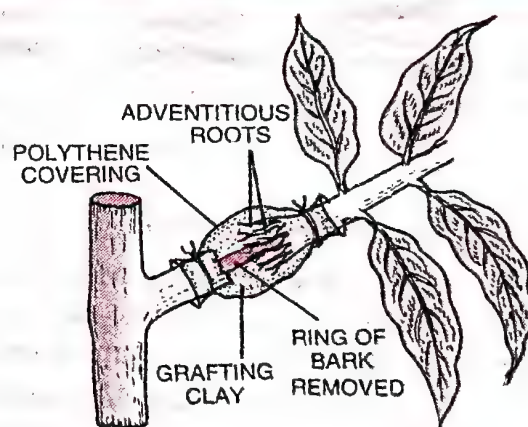


Fig. 1.24. Gootee (Air layering).

In grafting stock is always older than scion. Leaves and buds contained over the stump of stock are removed. Some common examples where grafting is practised are Mango, Apple, Pear, *Citrus*, Guava, Rubber Plant, Plum, Peach, Pine, etc. The various techniques of grafting are as follows :

(i) **Tongue Grafting.** Oblique sloping cut or notch is given to both stock and scion. The two perfectly fit into each other. They are tied together. Stock and scion are of same diameter.

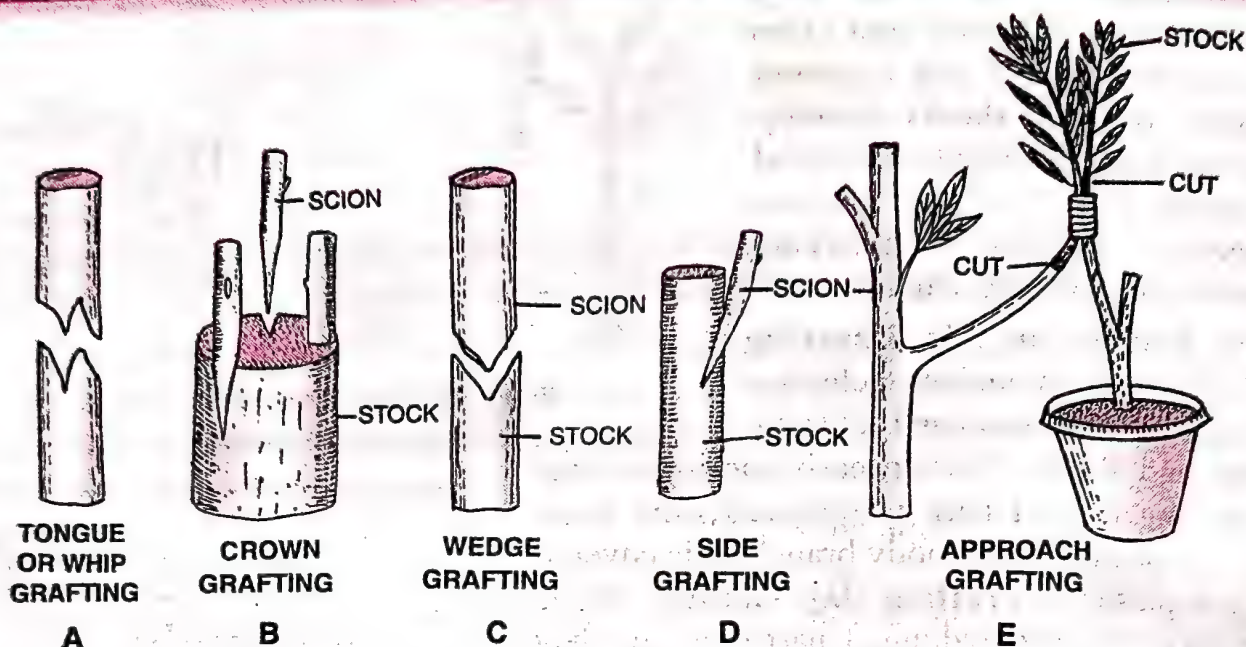


Fig. 1.25. A, Tongue or whip grafting. B, Crown grafting. C, Wedge grafting. D, Side grafting. E, Approach grafting.

(ii) **Crown Grafting.** Many scions are selected and paired at the base to form wedges. Many slits are formed on the sides of stock. Scions are inserted in the slits and bandaged. Stock has large diameter than scions.

(iii) **Wedge Grafting.** V-shaped notch is given to stock while wedge like cut is given to scion. Both are also of same diameter.

(iv) **Side Grafting.** V-shaped notch is given to stock at one side. One end of scion is sharpened. It is inserted in the stock. Stock also has larger diameter than scion.

(v) **Approach Grafting.** Two independently growing plants are brought together. The shoots of the two are given cuts at the same level for a distance of 2.5—5.0 cm. The cuts are in the form of removing smooth slices of bark (spliced approach grafting), **tongue shaped cuts** for interlocking and deeper **vertical cuts** if the stock is thicker than the scion.

The scion is cut below the graft while stock is cut above the graft after the establishment of union.

(4) **Bud Grafting** (Fig. 1.26). Scion is a bud with a small piece of bark and cambium. Stock is

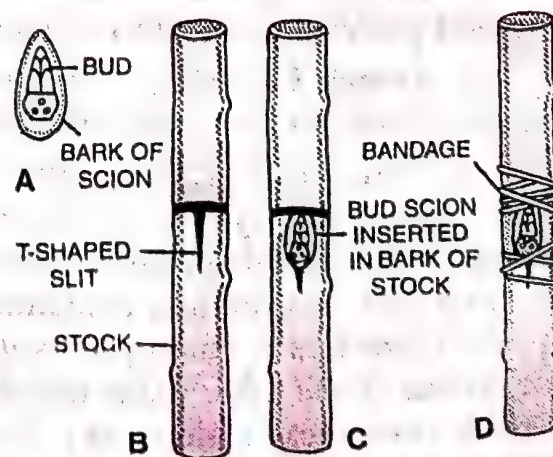


Fig. 1.26. Bud grafting.

given a T-shaped cut. Bark is lifted to expose cambium. Bud is inserted and the bark is allowed to come back to its original position. Only the bud is exposed. The joint is treated with grafting wax and bandaged. Bud develops after 3-5 weeks. Leaves and buds of the stock are removed. The stock is cut above the graft. Bud grafting is practised in Apple, Peach and Rose.

(5) **Micropropagation (Propagation by Plant Tissue Culture).** This method includes propagation of plants by culturing the cells, tissues and organs which is called **tissue culture***. Initially, the culturing of cells or tissues results in the formation of an undifferentiated mass of cells, called **callus**, which later differentiates to form a large number of plantlets. These plantlets are transferred to separate pots or nursery to grow them into plants. Tissue culture technique is useful in obtaining virus free plants, disease free plants, homozygous diploids and in quick commercial propagation of Orchids, Carnation, *Gladiolus*, *Chrysanthemum* and other ornamental plants.

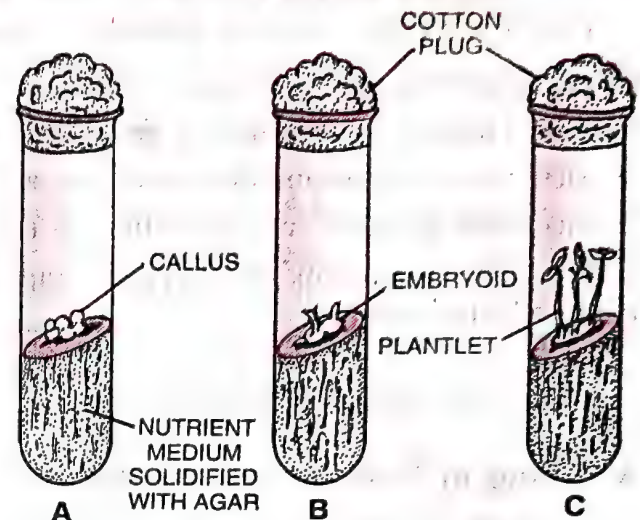


Fig. 1.27. Micropropagation.

(6) Use of Special Vegetative Organs.

Some of the vegetative parts which grow naturally are also used by horticulturists for vegetative propagation. Examples are rhizomes, tubers, suckers, stolons, corms, bulbs and bulbils.

Advantages of Vegetative Propagation

- (i) It is the only method of multiplication in seedless plants, e.g., Sugarcane, Banana, seedless Grape, seedless Orange, etc.
- (ii) The important advantage of vegetative propagation is that a plant can be retained and multiplied indefinitely without any change or variation.
- (iii) There is **rapid multiplication**.
- (iv) Since plants produced through micropropagation (tissue culture) are genetically identical, they show **genetic uniformity**.
- (v) Vegetative propagation by plant tissue culture (micropropagation) has been applied for the production of **disease-free plants**.
- (vi) The survival rate of daughter plants is almost 100 percent in vegetative reproduction.
- (vii) Good qualities of the plants can be preserved for a long time.
- (viii) Transgenic plants (genetically modified plants) can be produced using tissue culture.

Disadvantages of Vegetative Propagation

- (i) Vegetative propagules get easily decayed and are prone to viral, bacterial and fungal diseases.
- (ii) There are no variations. Therefore, the plants may show degeneration and in such plants there is a less adaptability to changed environment.
- (iii) There is no dispersal of vegetative propagules. Therefore, it causes over-crowding.

*Tissue Culture is dealt separately in Chapter 9.

Advantages of Asexual Reproduction

- (i) It is **uniparental** reproduction. Therefore, a mate is not required.
- (ii) It involves simple processes of division and mitosis.
- (iii) It is quick mode of reproduction.
- (iv) A single parent may produce a large number of offspring.
- (v) The young ones are genetically similar to their parent.

Disadvantages of Asexual Reproduction

- (i) There is no mixing of genetic material, therefore, no variation takes place.
- (ii) Since variations do not occur, asexual reproduction has no role in evolution.
- (iii) Due to rapid multiplication, it causes overcrowding.
- (iv) The organisms produced through asexual reproduction have low adaptability to the changed environment.

SEXUAL REPRODUCTION

Meaning of Sexual Reproduction

It is the process of development of new individuals through the formation and fusion of gametes. Sexual reproduction is also called **amphimixis** (Gk. *amphi* – both, *mixis* – union), **syngensis** (Gk. *syn* – together, *genesis* – origin) or **amphigony** (Gk. *amphi* – both, *gony* – marriage).

Sexual reproduction involves four processes : (i) formation of haploid cells, the **gametes**, by **gametogenesis** (meiosis), (ii) fusion of the two gametes forming diploid **zygote** (fertilization), (iii) repeated mitotic divisions of the zygote to form embryo (**embryogenesis**); and (iv) growth of embryo into new individual (**development**). Because there is fusion of two gametes, the offspring produced are not identical to their parents or fellows.

Characteristics of Sexual Reproduction. (i) It is usually biparental. (ii) Gametes are always formed. (iii) Fertilization takes place. (iv) It involves both meiosis and mitosis. (v) Daughter organisms genetically differ from the parents. (vi) Multiplication is not so rapid as in asexual reproduction.

Origin of Sex

Sex originated in protistans and simple algae. During favourable conditions, these organisms multiply asexually but during unfavourable conditions gametes are formed. The gametes seem to be starved asexual spores. They fuse to form zygotes which often develop a thick wall to become **zygospores**. The latter are dispersed. Under favourable conditions zygospore germinates to form new organisms (e.g., protist/alga).

Early sexual reproduction was **isogamous**. Later on evolution occurred and sexual reproduction became **anisogamous** and **oogamous**. Similarly sex organs evolved which differentiated into male and female. Early evolution of sex organs depended upon environment but later on hormones started influencing the development of sex organs.

In *Chlamydomonas* sexual reproduction may be isogamous, anisogamous or oogamous.

Occurrence

Sexual reproduction occurs almost in all types of plants and animals.

Types

Sexual reproduction is of two main types; syngamy and conjugation.

A. Syngamy (Gk. *syn* – together, *gamos* – marriage). It is the complete and permanent fusion of male and female gametes to form the zygote.

Syngamy is of two types with regard to the source of fusing gametes; endogamy and exogamy.

1. **Endogamy (Self-fertilization)**. It involves the fusion of male and female gametes of the same parent. Thus it is **uniparental**, e.g., *Taenia* (tape worm). *Taenia* is **hermaphrodite** (= monoecious or bisexual) worm.

2. **Exogamy (Cross-fertilization)**. It involves the fusion of two gametes produced by different parents. Thus it is **biparental**, e.g., Rabbit — dioecious or unisexual animal. Cross fertilization also occurs in many hermaphrodite animals as in earthworm and leech. It is due to the fact that their male and female reproductive organs mature at different times.

Differences between Self-Fertilization and Cross-Fertilization

Self Fertilization	Cross Fertilization
<ol style="list-style-type: none"> 1. It involves the fusion of male and female gametes of the same parent. Therefore, it is uniparental. 2. It is a rare process. 3. It increases homozygosity. 4. Very few variations develop in self fertilization. <p>Examples : <i>Taenia</i> (Tape worm).</p>	<ol style="list-style-type: none"> 1. It involves the fusion of two gametes produced by different parents. Therefore, it is biparental. 2. It is a common process. 3. It increases heterozygosity. 4. A lot of variations develop in cross fertilization. <p>Example : <i>Cockroach</i>, <i>Earthworm</i>, <i>Fish</i>, <i>Amphibians</i>, <i>Reptiles</i>, <i>Birds</i> and <i>Mammals</i>.</p>

Syngamy is of following types with regard to the structure of the fusing gametes; isogamy, anisogamy (heterogamy), oogamy and hologamy.

1. **Isogamy** (Gk. *iso* = equal; *gamos* = marriage). It involves the fusion of morphologically similar gametes or isogametes. Isogametes have the same structure and size. They are generally flagellate or planogametes, e.g., *Chlamydomonas* (an alga), *Microcystis* (a protozoan). The gametes of *Spirogyra* are nonflagellate or aplanogametes. They are morphologically similar but are functionally different. They bring about physiological anisogamy.

2. **Anisogamy**. It is fusion of gametes which are structurally similar but differ in size, e.g., *Chlamydomonas braunii*.

3. **Oogamy**. It involves the fusion of a large nonmotile female gamete or egg (= ovum) and a small motile male gamete called sperm or antherozoid, e.g., *Volvox*, *Fucus*, most animals.

4. **Hologamy** (Gk. *holos* = whole, entire, complete, *gamos* = marriage) or **Macrogamamy**. It involves the fusion of two organisms. It means two organisms themselves act as gametes. It occurs in yeasts.

B. Conjugation. It involves temporary union of two parents of the same species which exchange their male pronuclei to form synkaryon and then separate to produce daughter individuals. It corresponds to cross fertilization of higher animals. It takes place in *Paramecium*, *Spirogyra*, etc.

Differences between Isogamy and Anisogamy

Isogamy	Anisogamy
1. Fusing gametes do not differ in size, shape or function.	1. Fusing gametes differ in size, shape or motility.
2. Gametes cannot be differentiated into male and female.	2. Gametes can be differentiated into male (microgametes) & female (macrogametes).
3. Both the gametes are equally rich in nutrients.	3. Nutrients are more abundant in female gametes.
4. There is no difference in the activity of fusing gametes.	4. Male gametes are more active than the female gametes.
5. It takes place in unicellular organisms such as <i>Monocystis</i> – a protozoan.	5. It takes place in some fungi, higher invertebrates and all vertebrates.

Advantages of Sexual Reproduction

(Why is sexual reproduction better than asexual reproduction ?)

1. **Variations.** Since fusion of gametes from different parents occurs during sexual reproduction, hence genetic recombination takes place causing variations.

2. **Evolution.** Variation being a major factor of natural selection, therefore, it plays an important role in evolution.

3. **Adaptation.** The offspring produced due to sexual reproduction adapt better to the changing environmental conditions.

4. **Vigour and Vitality.** Genetic recombination and interaction during sexual reproduction provide vigour and vitality to the offspring.

Disadvantages of Sexual Reproduction

1. Sexual reproduction is usually biparental.

2. It is slow process and requires a lot of time.

3. Fertilization has a chance factor.

Differences between Asexual and Sexual Reproduction

Asexual Reproduction	Sexual Reproduction
1. It occurs in lower invertebrates and lower chordates and plants with simple organisations.	1. It occurs almost in all types of animals and mostly in higher plants.
2. It is always uniparental.	2. It is usually biparental.
3. Gametes are not formed.	3. Gametes are always formed.
4. No fertilization.	4. Fertilization takes place.
5. It involves only mitosis.	5. It involves both meiosis and mitosis.
6. Young ones are genetically identical to the parent.	6. Young ones differ genetically from the parents.
7. Multiplication occurs rapidly.	7. Multiplication is not so rapid as in asexual reproduction.
8. Since there is no variation, so it does not contribute to evolution of the species.	8. Since there are variations, so it contributes to evolution of the species.

PHASES IN LIFE CYCLE

There are three phases in an organism's life : juvenile phase, reproductive phase and senescent phase.

1. Juvenile Phase/Vegetative Phase

It is **prereproductive phase** in the life cycle of an individual. It is the *period of growth*

between the birth of an individual upto reproductive maturity. This phase has different structures such as different shapes of leaves, different colours of feathers of birds, different protections of the body. Juvenile phase is known as **vegetative phase** in plants. This phase is of different durations in different organisms.

2. Reproductive Phase (Maturity Phase)

The organisms reproduce offspring during this phase. Reproductive organs develop and mature during the period called **puberty**. Appearance of flowers in higher plants indicate sexual maturity. Sexually there are two types of flowering plants : monocarpic and polycarpic.

(i) **Monocarpic Plants.** These plants flower only once in their life. After flowering they produce fruits and die. All annual (e.g., Wheat, Rice) and biennial plants (e.g., Carrot, Radish) are monocarpic. A few perennial plants are also monocarpic. A few plants show unusual flowering behaviour— certain bamboo species, (e.g., *Bambusa tulda*) flower only once in their life time, usually after 50–100 years. They produce large number of fruits and then die. *Strobilanthes kunthiana* (Neelakuranji) flowers once in 12 years. The last time this plant flowered during September–October 2006. It is found in hilly areas in Kerala, Karnataka and Tamil Nadu and attracted a large number of tourists.

(ii) **Polycarpic Plants.** These plants are perennial and flower repeatedly at intervals every year (e.g., Apple, Mango, Orange, Grape vine). Very few perennial plants have flowers throughout the year (e.g., China Rose — Shoe Flower).

Differences between Monocarpic Plants and Polycarpic Plants

<i>Monocarpic Plants</i>	<i>Polycarpic Plants</i>
<ol style="list-style-type: none"> 1. Monocarpic plants flower only once in their life. 2. These plants are generally annual or biennial. Very few monocarpic fruits are perennial. 3. Monocarpic plants die after flowering and fruiting. Examples : Rice, Wheat, Radish, Carrot, Bamboo, etc. 	<ol style="list-style-type: none"> 1. Polycarpic plants flower every year in particular season. 2. These plants are perennial. 3. Polycarpic plants do not die after flowering and fruiting. Examples : Apple, Mango, Grape wine, Orange, etc.

Animal Breeding. On the basis of time of breeding, **animals** are of two types : seasonal breeders and continuous breeders.

(i) **Seasonal Breeders.** They reproduce at particular period of the year such as frog, lizards, most birds, deer, etc.

(ii) **Continuous Breeders.** These animals continue to breed throughout their sexual maturity. Examples are honey bee queen, poultry, rabbit, mice, cattle, etc.

In females of placental mammals, there are cyclical changes in ovaries, accessory reproductive ducts and hormones during the reproductive phase. These are of two types. In primates (monkeys, apes and humans) such cyclical changes during reproductive phase constitute **menstrual cycle**. Here, there is periodic sloughing off of inner lining of the womb. It is passed out along with some blood as menstruation. In non-primate mammals like cows, sheep, rats, deer, dogs, tiger, etc. such cyclical changes during reproduction form **estrus cycle**. There is a very strong urge of sex during the estrus. After the estrus the lining of the womb is sloughed off. It is not passed out but is reabsorbed. Depending upon the number of estrus cycles experienced in a year, the mammals are monoestrous (e.g., Deer), biestrous (e.g., Dog) or polyestrous (e.g., Mouse).

Differences between Menstrual and Oestrus Cycles (estrus = oestrous)

Menstrual Cycle	Estrus Cycle
<ol style="list-style-type: none"> 1. It occurs in primates (monkeys, apes and human beings) only. 2. This cycle consists of menstrual phase, proliferative phase and the secretory phase. 3. Blood flows in the last few days of this cycle. 4. The broken endometrium is passed out during menstruation. 5. Sex urge is not increased during menstruation. 6. Female does not permit copulation during menstrual phase of the cycle. 	<ol style="list-style-type: none"> 1. It occurs in nonprimates such as cows, dogs, etc. 2. It consists of a short period of <i>estrus</i> or heat (e.g., 12–24 hours in cow) followed by <i>anestrus</i> or passive period. 3. Blood does not flow in this cycle. 4. The broken endometrium is reabsorbed. 5. Sex urge is increased during estrus period. 6. Female permits copulation only during estrus period.

3. Senescent Phase (Senescence, Ageing)

It begins at the end of the reproductive phase when degeneration sets in structure and functioning of the body. Senescence is the last phase of life span. It ultimately leads to death.

In both plants and animals hormones are responsible for the change over from one phase to another. Hormones and certain environmental factors regulate the reproductive processes and the behaviour of the organisms.

Differences between Ageing and Senescence

Ageing	Senescence
<ol style="list-style-type: none"> 1. Ageing is progressive deterioration in the body of the organisms. There is general decline in metabolic processes. 2. It is not essential that ageing starts at the end of reproductive phase. 3. Ageing leads to senescence. 	<ol style="list-style-type: none"> 1. The terminal irreversible stage of ageing is called senescence. In plants it is characterized by yellowing and leaf fall. 2. Senescence (old age) starts at the end of reproductive phase. 3. Senescence leads to death.

Sexuality in Organisms. In most primitive sexually reproducing organisms, there is no morphological or physiological difference in the functional gametes. The gametes belong to the same parent. Such organisms are called **homothallic** (bisexual condition), e.g., *Mucor mucedo*. When the functional gametes belong to different parents as in *Rhizopus stolonifer*, and there is no morphological or physical difference, these organisms are called **heterothallic** (unisexual condition).

In higher organisms, sex organs developed, differentiated into male and female. In most flowering plants, both male and female sex organs (stamens and carpels) occur in the same flower. Such plants are called **hermaphrodite** or **bisexual**, e.g., sweet potato. In some flowering plants, male flowers (**staminate flowers**) and female flowers (**pistillate flowers**) are borne on different plants. These plants are called **dioecious plants**. Plants are either male or female, e.g., Date Palm, Papaya. When both male and female flowers are present on the same plants they are called **monoecious plants**, e.g., Maize, Coconut, Cucurbits. Lower plants are also monoecious and dioecious. *Chara* often bears both male (**antheridium**) and female (**oogonium**) sex organs. *Marchantia* a liverwort is dioecious. Here, the female plant bears archegonia over the **archegoniophore**. The male plant has **antheridia** over the **antheridiophore**.

Difference between Monoecious Plants and Dioecious Plants

<i>Monoecious Plants</i>	<i>Dioecious Plants</i>
<ol style="list-style-type: none"> Both male and female flowers are present on the same plant. Geitonogamy occurs. <p>Examples : Maize, Coconut, Cucurbits, Pinus.</p>	<ol style="list-style-type: none"> Male and female flowers are present on different plants. Geitonogamy is absent. <p>Examples : Date Palm, Papaya.</p>

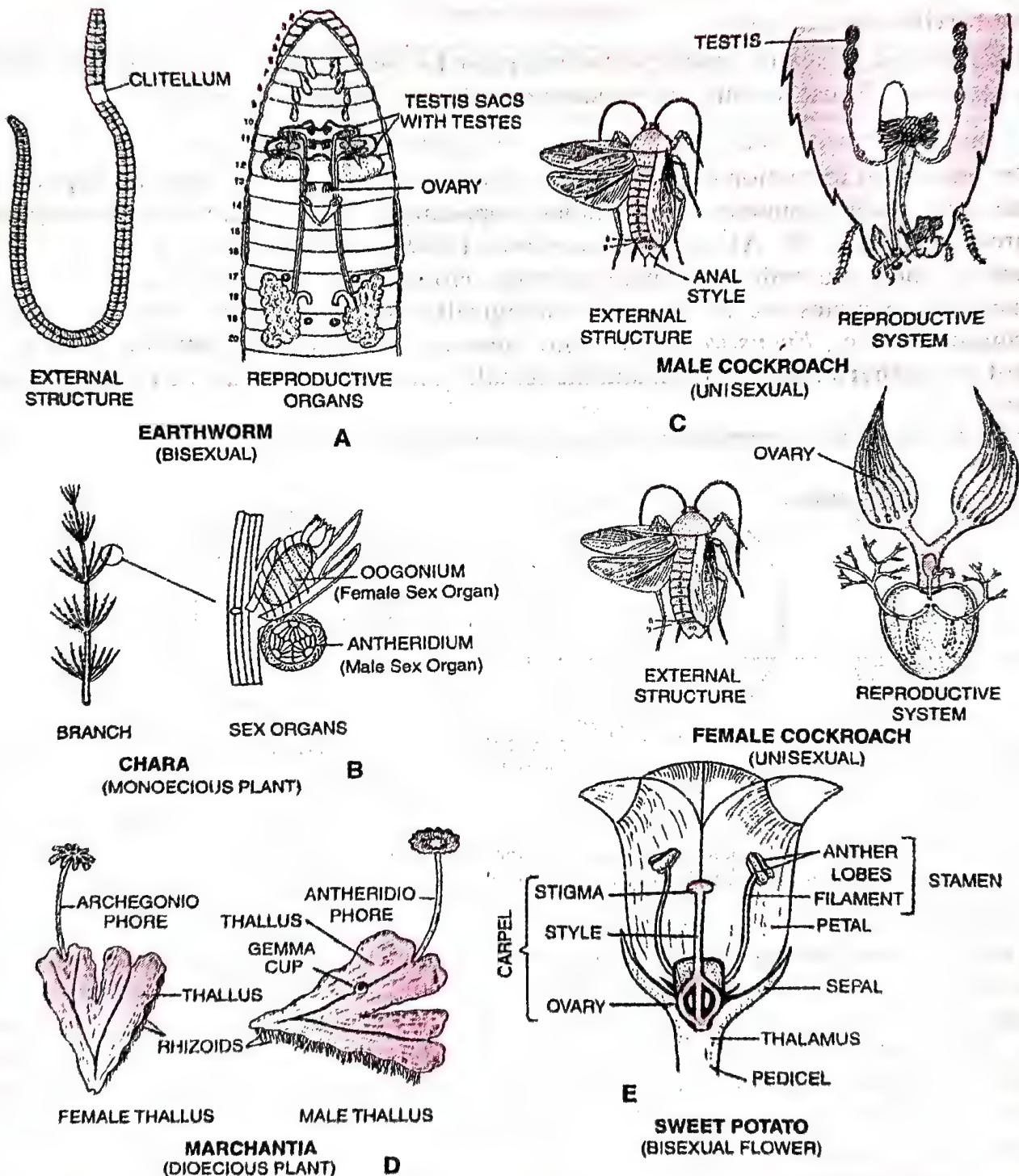


Fig. 1.28. Diversity of sexuality in organisms.

In some lower animals both male and female sex organs are present in the same individual. Such animals are called **hermaphrodite**, **monoecious** or **bisexual**, e.g., Tapeworm, *Fasciola*, Earthworm, Leech. It doubles the reproductive capacity as every individual can function both as male as well as female. Some animals also show sequential hermaphroditism. Most of animals are **unisexual** or **dioecious** with distinct male and female individuals, e.g., *Ascaris*, Cockroach, Frog, Lizards, Birds, Mammals.

EVENTS IN SEXUAL REPRODUCTION

These events may be grouped into three stages : The **pre-fertilization**, **fertilization** and the **post-fertilization** events.

1. Pre-fertilization Events

These events of sexual reproduction are prior to the fusion (fertilization) of male and female gametes. These events are **gametogenesis** and **gamete transfer**.

(i) Gametogenesis (Gk. *gametos* = gamete, *genesis* = production)

The process of formation of gametes is called gametogenesis. Gametes are haploid cells. In some algae, the two gametes are so similar in appearance that they are called **homogametes** (**isogametes** : Fig. 1.29. A), e.g., *Cladophora*, *Ulothrix*. Therefore, it is not possible to differentiate them into male and female gametes. However, in most of sexually reproducing organisms the gametes are of two morphologically dissimilar types. They are known as **heterogametes**, e.g., *Fucus* (a brown alga), humans. In these organisms the male gamete is called the **antherozoid** or **sperm** and the female gamete is known as the **egg** or **ovum** (Fig 1.29 B.C).

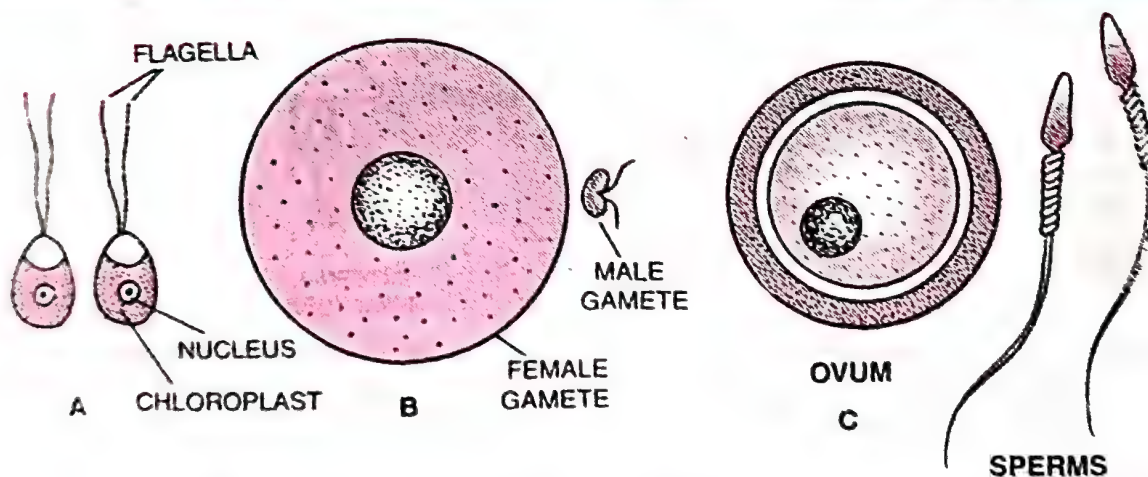


Fig. 1.29. Types of gametes. A, Isogametes of *Cladophora* (an alga). B, Heterogametes of *Fucus* (an alga) and C, Heterogametes of Human beings.

Cell Division During Gamete Formation. Gametes are always **haploid** whether the structures or cells producing them are haploid or diploid. The structure formed by the fusion of gametes is always diploid. Chromosome number is maintained by **meiosis** which occurs in the life of all sexually reproducing organisms. Meiosis also produces variations due to crossing over. Gamete producing cells which undergo meiosis are called **meiocytes** (gamete mother cells). The latter are diploid. *On the basis of the stage at which meiosis occurs the meiosis is of three types.*

(a) **Zygotic Meiosis.** Meiosis occurs in the zygote producing haploid organisms. Thus zygote functions as meiocyte. Examples : *Chlamydomonas*, *Ulothrix*.

(b) **Sporic Meiosis.** Meiosis occurs inside sporangia. It produces **haploid spores**. On germination, haploid spores (**meiospores**) produce haploid bodies called gametophytes. Gametes are produced in gametophytes through mitosis. Examples : most of plants.

(c) **Gametic Meiosis.** The germinal cells are diploid and act as meiocytes. They undergo meiosis to produce haploid gametes. Examples : most of animals.

Thus meiocytes have diploid ($2N$) number of chromosomes and gametes contain haploid (N) number of chromosomes.

Table 1.1 Chromosome numbers in meiocytes (diploid, $2N$) and gametes (haploid, N) of some organisms.

Name of organism	Chromosome number in meiocyte ($2n$)	Chromosome number in gamete (N)
Human beings	46	23
Housefly	12	6
Rat	42	21
Dog	78	39
Cat	38	19
Fruitfly (<i>Drosophila</i>)	8	4
Elephant	56	28
Apple	34	17
Rice	24	12
Maize	20	10
Potato	48	24
Butterfly	380	190
Onion	16	8
<i>Ophioglossum</i> (a fern)	1260	630

(ii) Gamete Transfer

The two types of gametes must be brought together for fertilization. In most of organisms male gamete is motile and the female gamete is nonmotile. However, there are a few fungi and algae where both types of gametes are motile (Fig. 1.30 A). A medium is needed through which male gametes move. In algae, bryophytes and pteridophytes, water serves as the medium through which gamete transfer takes place. Since most male gametes fail to reach the female gametes, they are produced in large number, *i.e.*, several thousand times more than the female gametes.

In flower bearing plants, pollen grains carrying the male gametes are produced in large number.

The pollen grains are transferred to the stigma of the female organ (carpal) through the process of **pollination**.

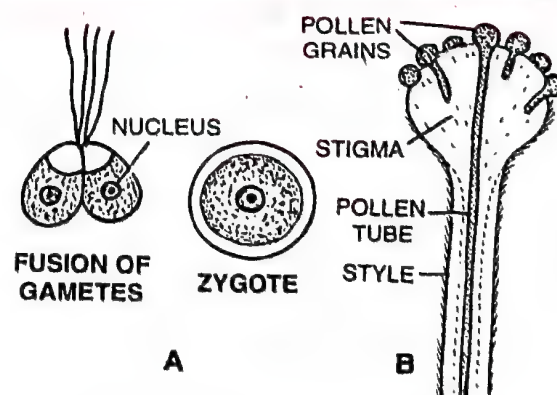


Fig. 1.30. A, Homogametic contact in an alga. B, Germinating pollen grains on stigma of a flower.

In **unisexual animals**, male and female gametes are formed in different individuals, therefore, the organism must evolve a special mechanism for gamete transfer. Many animals have copulatory organs to transfer the male gametes. Transfer of gametes and coming together of gametes is essential for fertilization in sexual reproduction.

2. Fertilization

Fertilization is the fusion of gametes to form a diploid **zygote**. This process is also called **syngamy**. The terms syngamy and fertilization are frequently used interchangeably.

Where does fertilization occur ? Fertilization occurs either in external medium (water) or inside the body of the organism. Thus there are two types of gametic fusion, namely external fertilization and internal fertilization.

(i) **External Fertilization.** When fertilization occurs outside the body of the organism, the gametic fusion is called **external fertilization** or **external syngamy**. It generally occurs in aquatic medium. Common examples are algae, fishes, and amphibians. Organisms exhibiting external fertilization produce a large number of gametes in water to enhance the chances of fertilization. This happens in bony fishes and frogs where a large number of offspring are produced. A major disadvantage of this type of fertilization is that the offspring are not protected from the predators and their survival is threatened upto adulthood.

(ii) **Internal Fertilization.** It is fusion of gametes inside the body of the female. **Internal fertilization** or **internal syngamy** occurs in terrestrial organisms belonging to fungi, higher animals such as reptiles, birds and mammals and majority of bryophytes, pteridophytes, gymnosperms and angiosperms are the examples where internal fertilization occurs. Here male gamete is mobile and has to reach the egg in order to fuse with it. The number of sperms produced is very large but there is reduction in the number of eggs produced. However, in seed plants, the non-motile male gametes are carried to the female gamete by pollen tubes.

Differences between External Fertilization and Internal Fertilization

<i>External Fertilization</i>	<i>Internal Fertilization</i>
<ol style="list-style-type: none"> 1. It occurs outside the body of the female. 2. Both the types of gametes are released from the body. 3. A large number of gametes are released in the surrounding medium (e.g., water) where fertilization takes place. 4. The young ones develop unprotected from the beginning. 5. It involves a large degree of chance. <p>Examples : Bony fish, Amphibians, most of Algae, etc.</p>	<ol style="list-style-type: none"> 1. It occurs inside the body of the female. 2. Only the male gametes are released from the body. 3. The number of gametes produced is less. The male gametes pass into the body of the female. 4. The young ones are protected during their early development. 5. It is a surer method. <p>Examples : Reptiles, Birds, Mammals, Bryophytes & Tracheophytes (Pteridophytes, Gymnosperms, Angio-sperms), etc.</p>

3. Post Fertilization Events

Events in sexual reproduction after the fertilization (formation of zygote) are called post-fertilization events. These events include development in zygote and embryogenesis.

(i) Zygote

A diploid zygote is fertilization product in all sexually reproducing organisms. It is vital link between one generation and the next generation. In external fertilization, zygote is formed in the external medium (usually water) whereas in internal fertilization, zygote is formed inside the body of the female.

Further development of the zygote depends on the type of life cycle of the organism and environmental conditions.

(a) In many fungi and algae, the zygote develops a thick wall and forms spore called **zygospore**. Zygospore undergoes a period of rest. It germinates during next growing season. The zygospore undergoes meiosis to produce haploid individuals. It leads to a **haplontic life cycle**.

(b) In most animals, zygote does not take rest. It divides by mitosis first forming a diploid embryo and then the individual which is also diploid. It leads to a **diplontic life cycle**.

(c) In most plants the zygote first forms an embryo and then the diploid sporophyte. The sporophyte has sporangia where meiosis takes place to form haploid spores. The latter produce haploid gametophytes. Gametes are produced in the gametophytes. It leads to a **diplohaplontic life cycle**.

Differences between Zoospore and Zygote

<i>Zoospore</i>	<i>Zygote</i>
<ol style="list-style-type: none"> 1. Zoospore is formed inside the zoosporangium. 2. It is motile. 3. Zoospore is the result of asexual reproduction. 4. It is haploid or diploid. 5. Zoospore takes part in dispersal. 	<ol style="list-style-type: none"> 1. It is formed by fusion of two gametes. 2. It may be non-motile or motile. 3. It is the net result of sexual reproduction. 4. It is always diploid. 5. It has little role in dispersal.

(ii) Embryogenesis

The process of development of **embryo** from the zygote is called **embryogenesis**. During embryogenesis zygote undergoes **mitotic cell division** and **cell differentiation**. Cell division increases the number of cells in the developing embryo while cell differentiation helps to form specialised tissues and organs to form an organism.

Differences between Gametogenesis and Embryogenesis

<i>Gametogenesis</i>	<i>Embryogenesis</i>
<ol style="list-style-type: none"> 1. It is the formation of haploid gametes. 2. It is of two types (a) spermatogenesis (formation of male gametes) and (b) Oogenesis (formation of female gametes). 3. Meiosis occurs during gametogenesis. 4. It leads to fertilization. 	<ol style="list-style-type: none"> 1. It is the formation and development of a multicellular embryo from unicellular zygote. 2. It involves cell division to increase the number of cells, cell growth and cell differentiation (formation of different kinds of tissues). 3. Mitosis occurs during embryogenesis. 4. It leads to organogenesis (organ formation).

(i) On the basis of the development of the zygote, **animals** are grouped into **oviparous**, **viviparous** and **ovoviviparous**. The oviparous animals lay fertilized or unfertilized eggs. In land animals such as reptiles and birds the fertilized eggs are covered by hard **calcareous shell** and are laid in a safe place in the **environment**. After incubation period, youngones hatch out. In viviparous animals such as majority of mammals including human beings, the

zygote develops into a young one inside the body of the female individual. After a certain growth, the young ones are delivered by the female individual. Due to proper care and protection, the chances of survival of young ones are more in viviparous individuals. In ovoviviparous animals, the female retains the eggs inside its body after fertilization and allows the development of the embryo inside the body without providing extra nourishment to the developing embryo as the placenta is absent. However, the female animals give birth to the young ones. Examples of ovoviviparous animals are sharks and rattle snakes.

Differences between Oviparous and Viviparous Animals	
Oviparous Animals	Viviparous Animals
<ol style="list-style-type: none"> 1. Females lay fertilized/unfertilized eggs. 2. Eggs are surrounded by a protective covering. 3. The development of embryo takes place outside the female's body. 4. Females lay eggs in a safe place in the environment but the chances of survival are less. <p>Examples : All Birds, most of Reptiles and Egg-laying Mammals.</p>	<ol style="list-style-type: none"> 1. Females give birth to young ones. 2. A protective covering is absent around the eggs. 3. The development of embryo takes place inside the female's body. 4. Females deliver young ones and the chances of survival are more. <p>Examples : Mammals except Egg-laying Mammals.</p>

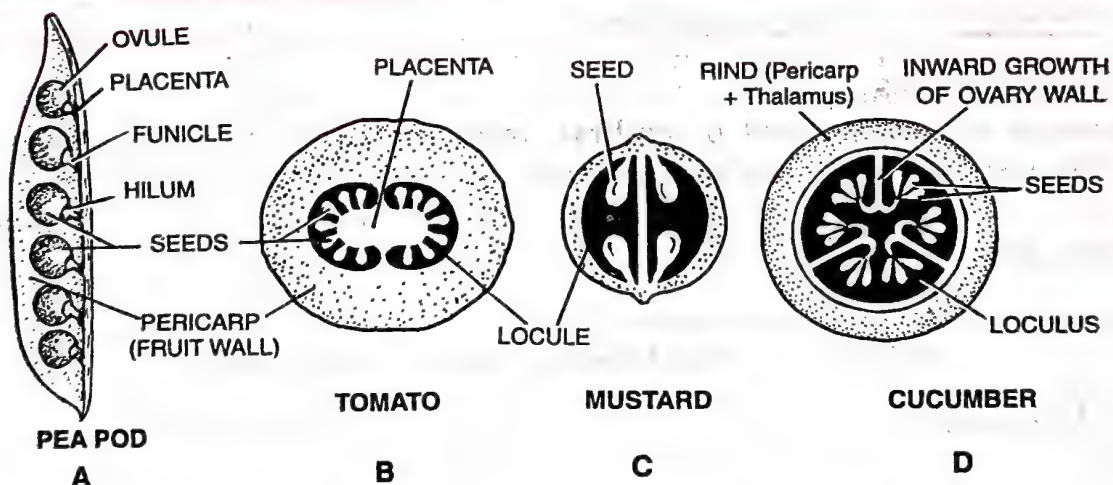


Fig. 1.31. A few kinds of fruits showing seeds and protective pericarp.
A, L.S. Pod (Fruit) of Pea. B, C & D, T.S. ovaries.

(ii) In **flowering plants**, the zygote is formed inside the ovule of the female sex organ. After fertilization, the sepals, petals and stamens of the flower become faded and fall off. The sepals may remain attached as in *Hibiscus*. However, the pistal remains attached to the plant.

Seed and Fruit Formation. In angiosperms double fertilization produces two structures — a diploid zygote (= oospore) and a triploid primary endosperm cell. Zygote forms the embryo. The triploid primary endosperm cell gives rise to a nutritive tissue called **endosperm**. Endosperm provides food to the growing embryo. The fertilized ovules mature and convert into **seeds**. The wall of the ovary forms the **pericarp** (fruit wall). The ripened ovary with pericarp and seeds is called fruit. The pericarp protects the young seeds. After dispersal the seeds germinate to form new plants.

Maintenance of Chromosome Number (Fig. 1.32)

The reproductive units in sexual reproduction are the male and female gametes that are produced by testes and ovaries respectively. The gametes are haploid with only N chromosomes. Consequently the zygote resulting from fusion of two such haploid gametes becomes diploid with $2N$ chromosomes. The offspring that develops from the zygote is also diploid.

PARTHENOGENESIS (VIRGIN BIRTH)

Definition. Development of an egg (ovum) into a complete individual without fertilization is known as parthenogenesis. Parthenogenesis was discovered in animals by Charles Bonnet in 1745.

Occurrence. Parthenogenesis (Gr. *parthenos* = virgin, *genesis* = produce) occurs in its natural course in many invertebrates such as rotifers (wheel animals), arthropods, viz., crustaceans (e.g., *Apus*, *Cypis*, *Daphnia*), insects (e.g., bees, wasps, beetles, ants, aphids, grasshoppers, weevils, gall flies) and arachnids (e.g., spiders, ticks, mites) and some vertebrates such as *Lacerta saxicola armaniaca* (Caucasian rock lizard), *Typhlina brahmina* (a small snake of India) and some birds (e.g., turkeys). However, artificial (induced) parthenogenesis is found in annelids, molluscs, echinoderms, amphibians and even mammals.

Types. Parthenogenesis is of two main types : natural and artificial.

A. Natural Parthenogenesis. It occurs regularly in the life cycle of certain animals. It may be complete, incomplete or paedogenetic.

(a) **Complete (Obligatory) Parthenogenesis.** It occurs in those animals which *breed exclusively by parthenogenesis*. It means parthenogenesis is the only form of reproduction in some animals and there is no biparental sexual reproduction. There are no *males* and, therefore, such individuals are represented by *females* only.

Exmaples: (i) *Lacerta saxicola armaniaca* (Caucasian Rock Lizard)—lizard from Armania (name of a country)

(ii) *Typhlina brahmina* perhaps the most widely distributed small snake.

(b) **Incomplete (Cyclic) Parthenogenesis.** It is found in those animals in which both sexual reproduction and parthenogenesis occur.

Examples : (i) In **honey bees**, fertilized eggs (zygotes) give rise to queens and workers (both are females) and unfertilized eggs (ova) develop into drones (males).

(ii) In spring, eggs (ova) of **aphids** develop into females which produce many generations of females by parthenogenesis through the summer months. At the end of summer some females produce males and females by parthenogenesis. Both of these males and females mate to produce fertilized eggs (zygotes) that hatch in the spring as parthenogenetic females to continue parthenogenesis. Thus **cyclic parthenogenesis** is found in aphids.

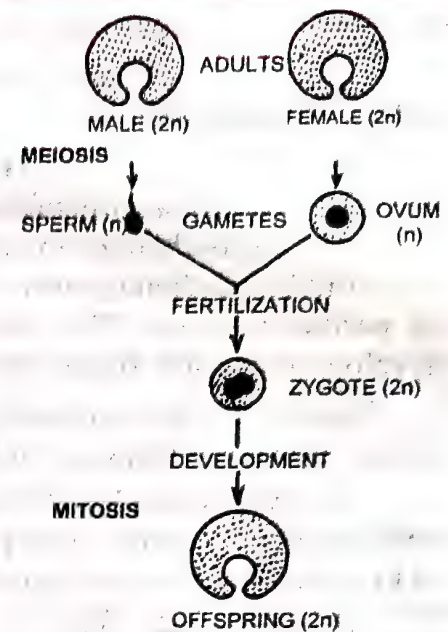


Fig. 1.32. Schematic representation of sexual reproduction showing how chromosome number remains constant.

(iii) Some species of wasps produce alternately a parthenogenetic generation and one which develops from fertilized eggs.

(iv) About 40% male turkeys are produced by parthenogenesis and 60% males and all females are produced by sexual reproduction.

(c) **Paedogenetic Parthenogenesis.** When parthenogenesis occurs in larva it is called *paedogenetic parthenogenesis*. It is found in the life cycle of the liver fluke. **Miracidium** is its first larva. It changes to second larva, the **sporocyst**. The sporocyst produces third larva, the **redia** by parthenogenesis. The redia produces more rediae and fourth larva, the **cercaria** by parthenogenesis. The cercaria changes to fifth larva, the **metacercaria**. Metacercaria develops into adult fluke. Thus parthenogenesis occurs in sporocyst and redia.

Natural parthenogenesis is also classified on the basis of sex of offspring. Based on the sex of offspring, there are following three types of parthenogenesis.

(i) **Arrhenotoky** (Gk *arrhen*—male, *tokos*—birth). In this type of parthenogenesis, only males are produced by parthenogenesis. It occurs in rotifers, bees (honey bees), wasps, ticks, mites and certain spiders.

(ii) **Thelytoky** (Gk. *thelys*—female, *tokos*—birth). In this type of parthenogenesis, only females are produced by parthenogenesis. It occurs in *Solenobia* of Lepidoptera*, *Lacerta saxicola armaniaca*, *Ramphotyphlops braminus*, etc.

(iii) **Amphitoky** (Gk. *amphi*—both, *tokos*—birth). In this type of parthenogenesis, parthenogenetic egg may develop into individual of any sex (i.e., male or female). It occurs in *Aphis* (aphid).

B. Artificial Parthenogenesis. In this type of parthenogenesis, the egg (ovum) is induced to develop into a complete individual by artificial stimuli. Artificial parthenogenesis may be induced by physical as well as chemical stimuli.

(i) **Physical Stimuli.** These include changes in temperature and pH, electric shock, ultra-violet light, and mechanical stimulus (e.g., prick by a needle).

(ii) **Chemical Stimuli.** These include changes in the salt concentration of the surrounding water, application of chloroform, ether, alcohol, urea, fatty acids, etc.

Examples : Eggs (ova) of annelids, molluscs, echinoderms (sea urchin, star fish), frogs, salamanders, birds (turkey, hen) and even mammals (rabbit) may be induced by physical or chemical stimuli to develop parthenogenetically into complete individuals.

Significance of Parthenogenesis. (a) **Advantages.** (i) It is a simpler and easier means of reproduction.

(ii) It represents a method of rapid multiplication.

(iii) Parthenogenesis permits establishment of triploid and aneuploid chromosomal combinations.

(iv) Parthenogenesis is a means of sex determination in some animals such as in honeybees. Thus it supports the chromosomal theory of sex determination.

(b) **Disadvantages.** Parthenogenesis eliminates variation in a population so it does not play any role in organic evolution.

Conclusion. Occurrence of parthenogenesis shows that the egg (ovum) has all the factors essential for development and only needs a stimulus to activate it for development.

*Lepidoptera is an order of class Insecta. It includes butterflies and moths.

In normal sexual reproduction sperm entry into the ovum provides the stimulus. In some animals an artificial stimulus is applied and in some no stimulus is needed.

ADDITIONAL INFORMATION

- Many people look older than their real age, it is called **geromorphism**.
- Longevity or life span of an individual is called **Macrobiosis**.
- Vladimir Korenchevsky is considered **Father of gerontology**.
- An alternative term for regeneration is called **Neogenesis**.
- Old age, sum of physical and mental changes occurring in advanced age is called **Senility**.
- **Smallest pollen** : *Myosotis* (2.5–3.5 μm)
- **Biggest pollen** : *Mirabilis* (250 μm in diameter)
- **Largest flower** : *Rafflesia* (1m).
- **Smallest flower** : *Wolffia arrhiza* (= *W. microscopia*)
- **Largest fruit** : *Lodoicea maldivica* (Double coconut).
- **Largest seed** : *Lodoicea maldivica* (Double coconut), the fresh weight of seed is about 6 kg.
- **Smallest seed** : Orchid.
- *Erythrina* flowers are pollinated by cows and squirrels.
- Pollen grains of many plants cause allergies (e.g., *Parthenium hysterophorus*, *Prosopis juliflora*, *Sorghum vulgare*, *Chenopodium album*, *Cynodon dactylon*, *Ricinus communis*, *Amaranthus spinosus*, etc.) Some of the common allergies are hay fever depression, bronchitis, etc.
- **Cryptorchidism**. The testes remain in the abdominal cavity and do not descend into the scrotal sac. It leads to sterility in man.
- Two ovaries alternate in ovulation.
- **Intra-abdominal Testes**. Testes that remain permanently in the abdomen, e.g., elephant, Whale, seal and egg laying mammals—*Echidna* (spiny ant eater), Duck-bill (*Platypus*).
- **Strobilanthus**. Plant that flowers once in 12 years.
- **Metagenesis**. Alternation of diploid sexual and diploid asexual generation in the life cycle of *Obelia*.
- **Capacitation**. The preparation of sperm to fertilize the ovum.
- **Gerontology**. It is the study of process of ageing.
- **Aplanospore**. A thin walled nonmotile spore, one that is carried passively by wind, water or other organisms.
- **Pollinium**. A mass of pollen that sticks together and is transported by pollinators as a mass; present in orchids and milkweeds.
- **Blastogenesis**. Formation of young ones from reproductive units (**blastos**) such as buds or fragments, in asexual reproduction is called **blastogenesis**.
- **Panchanan Maheshwari** (1904–1966) "Father of Indian Embryology of Plants".

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. Why is reproduction essential for organisms ?
✓ Reproduction is essential for organisms because it enables the continuity of the species generation after generation.
2. Which is a better mode of reproduction sexual or asexual ? Why ?
✓ Sexual reproduction is better mode of reproduction because it causes genetic variation which is essential for evolution and survival of species under unfavourable conditions.
3. Why is the offspring formed by asexual reproduction referred to as clone ?
✓ Since the offspring (individuals) formed by asexual reproduction are morphologically and genetically similar, they are called clones.
4. Offspring formed due to sexual reproduction have better chances of survival. Why ? Is this statement always true ?

- ✓ Offspring formed by sexual reproduction have better chances of survival because they have the genetic material of two parents and that too shows variation. This is important for the survival of species. This statement is always true.
5. How does the progeny formed from asexual reproduction differs from those formed by sexual reproduction ?
 ✓ Since asexual reproduction does not involve meiosis and fusion of gametes, the progeny formed from asexual reproduction are genetically similar to parents and they do not show variation. In sexual reproduction, the individuals produced as a result of meiosis and gametic fusion and show genetic variation and are better adapted to environmental conditions.
 6. Distinguish between asexual and sexual reproduction. Why is vegetative reproduction also considered as a type of asexual reproduction ?
 ✓ For differences refer to the text Differences Between Asexual and Sexual Reproduction. Since vegetative reproduction does not involve meiosis and fusion of gametes, it is considered as type of asexual reproduction.
 7. What is vegetative propagation ? Give two suitable examples.
 ✓ The vegetative propagation involves production of new plants from some vegetative plant propagules (vegetative structures of the plants) such as buds, rhizomes, suckers, tubers, etc.
Examples. (1) Potato tubers possess buds which grow into new plants.
 (2) Adventitious buds of *Bryophyllum* leaves grow to form new plants.
 8. Define (a) Juvenile phase (b) Reproductive phase (c) Senescent phase
 ✓ (a) It is the period of growth between the birth of an individual upto reproductive maturity.
 (b) It starts after juvenile phase and remains upto the stage when an organism is capable of reproduction.
 (c) It is the phase of ageing when an organism loses its capacity of reproduction. In plants it is characterised by yellowing and leaf fall.
 9. Higher organisms have resorted to sexual reproduction in spite of its complexity. Why?
 ✓ Because it enables these organisms to survive during unfavourable conditions. It contributes to evolution of the species by introducing variation in a population.
 10. Explain why meiosis and gametogenesis are always interlinked ?
 ✓ In sexual reproducing organisms, meiosis occurs during gametogenesis to reduce the diploid number of chromosomes (2N) to haploid number of chromosomes (N) in the gametes. Thus, gametes are formed as a result of meiosis so that their chromosome number becomes haploid.
 11. Identify each part in a flowering plant and write whether it is haploid (N) or diploid (2N).
 (a) Ovary _____ (b) Anther _____
 (c) Egg _____ (d) Pollen _____
 (e) Male gamete _____ (f) Zygote _____
 ✓ (a) Diploid (2N) ; (b) Diploid (2N) ; (c) Haploid (N) ; (d) Haploid (N) ; (e) Haploid (N) ;
 (f) Diploid (2N)
 12. Define external fertilization. Mention its disadvantages.
 ✓ **External Fertilization.** External fertilization is the fusion of compatible gametes outside the body of organisms, e.g., Frog, Fish, etc.
Disadvantages of External fertilization. (1) It occurs only in aquatic medium. (2) A chance factor is involved requiring synchronous release of gametes nearby and absence of turbulence of water. (3) There is no protection to young ones. They are vulnerable to a number of predators.
 13. Differentiate between a zoospore and a zygote.
 ✓ Refer to the text Differences between Zoospore and Zygote.
 14. Differentiate between gametogenesis from embryogenesis.
 ✓ Refer to the text Differences between Gametogenesis and Embryogenesis.
 15. Describe the post-fertilization changes in a flower.
 ✓ After fertilization, the following changes occur in a flower. (1) The sepals, petals, stamens, style and stigma are shed. In some cases the sepals remain persistent, e.g., Pea. (2) The zygote develops into embryo. (3) The fertilized ovule changes into seed. (4) The wall of ovary produces wall of the fruit called pericarp. (5) The ripened ovary with pericarp and seeds is called fruit.

16. What is a bisexual flower ? Collect five bisexual flowers from your neighbourhood and with the help of your teacher find out their common and scientific names.

✓ **Bisexual flower.** The flower which contains both male and female sex organs (stamens and carpels) in the same flower is called bisexual flower.

	Common Name	Scientific Name
(i)	Rose	<i>Rosa alba</i>
(ii)	Kikar	<i>Acacia nilotica</i>
(iii)	Sweet Pea	<i>Lathyrus odoratus</i>
(iv)	Kachnar	<i>Bauhinia variegata</i>
(v)	Shoe flower, Gurthal, China flower	<i>Hibiscus rosa-sinensis</i>

17. Examine a few flowers of any cucurbit plant and try to identify the staminate and pistillate flowers. Do you know any other plant that bears unisexual flowers ?

✓ In staminate flowers (male flowers) stamens (male reproductive organs) are present and carpels or pistils (female reproductive organs) are absent. They do not develop fruits. In pistillate flowers (female flowers) carpels or pistils are present and stamens are absent. They develop fruits. The other unisexual plant is papaya. Date Palm is also unisexual.

18. Why are offspring of oviparous animals at a greater risk as compared to offspring of viviparous animals ?

✓ Oviparous animals lay eggs which are not always safe and offspring are always at a risk. Thus both eggs and offspring are not protected against unfavourable environmental conditions and predators.

TEXT QUESTIONS

One Mark Questions (With Answers)

- Do you know a special feature about flowering of *Strobilanthes kunthiana* (Neelakuranji) ?
✓ It flowers once in 12 years.
- Name the kind of reproduction in bees in which drones are produced.
✓ Parthenogenesis.
- Give one example of a unicellular organism in which isogamy occurs.
✓ Monocystis.
- What is special in flowering of bamboo ?
✓ Bamboo species flower only once in their life time, generally after 50–100 years.
- How does the *Bryophyllum* reproduce vegetatively ?
✓ *Bryophyllum* reproduces vegetatively by epiphyllous buds on leaves, each of which grows into a new plant.
- What is meiocyte ?
✓ The cell which undergoes meiosis is called a meiocyte.
- Where is a zygote formed in a flowering/seed plant ?
✓ It is formed inside the ovule
- Why is reproduction essential for organisms ?
✓ Reproduction is essential to continue the race.
- Which is better mode of reproduction, sexual or asexual ?
✓ Sexual reproduction is better mode of reproduction than asexual.
- Offspring formed due to sexual reproduction have better chances of survival. Why ?
✓ They adapt better to the changing environmental conditions. Sexual reproduction provides vigour and vitality to the offspring.
- Define Regeneration.
✓ Regeneration is the formation of the whole body of the organism from a small fragment or the replacement of the lost part.
- Name the mode of reproduction in yeast.
✓ By budding process

(CBSE 2010)

13. Define Geitonogamy.
✓ It is a type of pollination in which pollen grains of one flower are transferred to the stigma of another flower belonging to either the same plant or genetically similar plant.
14. Define Palynology.
✓ Palynology is a branch of botany that deals with study of morphology of fossil spores, pollens etc, (CBSE 2010)
15. Why is the apple referred to as a false fruit ?
✓ In most plant, the fruits develops from the ovary, other floral parts degenerate and fall off. But in apple the thalamus also contributes to fruit formation. So apples are called 'false fruits'.
16. Name an organism where cell division in itself is a mode of reproduction. (CBSE 2013)
✓ *Amoeba*
17. Name an organism that reproduces asexually through zoospores. Why are these reproductive units so called? (CBSE 2013)
✓ *Ulothrix*. Zoospores are named so because they are flagellated and motile (like animals) spores.
18. Name the phenomenon and one bird where female gamete directly develops into a new organism.
✓ Parthenogenesis : Turkey (CBSE 2013)
19. Name the vegetative propagules in (i) *Agave* (ii) *Bryophyllum*. (CBSE 2014)
✓ (i) Bulbil (ii) Leaf
20. Write the name of the organism that is referred to as the 'Terror of Bengal'. (CBSE 2014)
✓ *Eichhornia crassipes* (Water Hyacinth)
21. Meiosis is an essential event in the sexual life cycle of an organism. Give the reasons. (CBSE 2015)
✓ (i) Reduce chromosome number to half in gametes.
(ii) Maintain number of chromosomes constant in organisms.

Two Mark Questions

1. Name the four stages of life span.
✓ Four stages of life span are (i) juvenile (ii) maturity (iii) ageing and senescence and (iv) death.
2. What is plasmotomy ? Give two examples of it.
✓ It is division of a multinucleate parent into many multinucleate individuals without division of nuclei. It occurs in *Opalina* and *Pelomyxa*.
3. Differentiate between parthenocarpy and parthenogenesis.
✓ Parthenocarpy is "the formation of fruits without fertilization" where as parthenogenesis is "the formation of embryo from unfertilized egg".
4. Write the modes of asexual reproduction in the following organisms; *Bryophyllum*, Potato, Yeast, *Rhizopus*, *Penicillium*.
✓ The modes of reproduction are listed below :
1. *Bryophyllum*. Reproduce asexually by formation of marginal adventitious buds in mature leaves.
2. Potato. Buds in the eyes in potato tuber grow to form aerial shoots.
3. Yeast. Budding
4. *Rhizopus*. Sporangiospores formed inside sporangia.
5. *Penicillium*. Conidia formed on conidiophores.
5. Give the chromosome number in the gametes of the following if the number of chromosomes in their meiocyte is as follows : (i) Dog – 78, (ii) Housefly – 12, (iii) Rice – 24, (iv) Onion – 16
✓ (i) Dog – 39, (ii) Housefly – 6, (iii) Rice – 12 (iv) Onion – 8
6. What is the major difference you observe in progeny produced by asexual reproduction and the progeny produced by sexual reproduction. (CBSE 2008)
7. How does *Penicillium* reproduce asexually ? (CBSE 2011)
8. Why do algae and fungi shift to sexual reproduction just before the onset of adverse conditions? (CBSE 2014)
9. Why do moss plants produce very large number of male gametes ? Provide one reason. What are these gametes called ? (CBSE 2015)
10. Explain the significance of meiocytes in a diploid organism. (CBSE 2016)
11. Explain the importance of syngamy and meiosis in a sexual life cycle of an organism. (CBSE 2016)

Three Mark Questions (Short Answer Type)

- How has sex originated ?
- Explain the various types of meiosis ?
- How do roots take part in vegetative propagation ?
- Define life span of an organism. Mention the life span of (i) crocodile (ii) crow (iii) parrot & (iv) butterfly.
- How does yeast produce asexually ? Show it diagrammatically.
- Coconut palm is monoecious while date is dioecious. Why are they called so ? (CBSE 2008, 2014)
- (a) List the three stages, the annual and biennial angiosperms have to pass through during their life cycle.
(b) List and describe any two vegetative propagules in flowering plants. (CBSE 2017)
- Differentiate between an annual and a biennial plant. Provide one example of each. (CBSE 2017)

Five Mark Questions (Long Answer Type)

- Explain the following terms (i) neoteny (ii) polyembryony (iii) parthenogenesis
- Describe five modes of asexual reproduction in animals.
- Describe the major events in sexual reproduction.
- (i) Define clone
(ii) How is *Bryophyllum* multiplied ?
(iii) When did flowering occurs last time in *Strobilanthes kunthiana* ?
(iv) What are monocarpic and polycarpic plants ?
(v) What is "terror of Bengal" ?

Value Based Question

- Seeing a heap of cut Potato tubers in one corner of a field, Rohit asked his father why has the farmer placed so many cut potatoes there? What is the importance of the practice being followed by the farmer ?
✓ Father told Rohit that potatoes are not grown from seeds but pieces of tubers. For sowing, the tubers are cut into pieces, with each piece having one or more eyes. It is a method of vegetative reproduction. The technique is helpful in raising a new crop in about four months. When grown from seeds, the crop requires 15 months to mature. Here human ingenuity has helped in shortening the crop period. The raised crop is of uniform quality. Sexual reproduction is resorted to only when cross breeding and other modifications are to be carried out in research stations.
- Mother tells Manas to always cover the bread and place it in the fridge instead of leaving it unwrapped on the table. Why? What harm would it cause if the bread is kept unwrapped. What lesson do we obtain from the same.
✓ Spores of saprophytic fungi roaming in the air, settle over exposed food articles, grow there and spoil the food. Exposed bread is an ideal substratum for *Rhizopus* (Bread Mould) to settle, grow and form mycelia over the same. This not only spoils the bread but also makes it toxic. Therefore, the mother was directing Manas to wrap the bread and keep it in fridge. In fridge, the temperature being low the few spores even if settled over bread, will not be able to grow.
Values. (i) No food article should be kept exposed, (ii) We should not eat exposed food articles from vendors as they are likely to be contaminated by flies, dust and air borne saprophytes and pathogens. (iii) Shelf life of food article increases by keeping it in fridge as its low temperature reduces the activity of microbes and enzymes.

Miscellaneous

- Match the items in Column A with appropriate items in Column B

Column A	Column B
(a) Zygote	(i) Monocystis
(b) Bird Pollination	(ii) Genetically identical offspring
(c) Clone	(iii) Red silk cotton
(d) Isogamy	(iv) Earthworm
(e) Bisexual animal	(v) Embryo

2. Fill in the blanks :

- Fusion of two results in the formation of zygote.
- Development of from the is called embryogenesis.
- animals lay egg.
- After fertilization are transformed into seeds.

3. For the following statements, write 'T' for true and 'F' for false statements.

- Amoeba* is called immortal because it does not undergo natural death.
- Man has restorative regeneration power, while *Hydra* has only reparative regeneration power.
- The ovary ripens to form fruit.
- Rhizopus* is also called bread mould.
- Parrot has lifespan of 140 years.
- Meiosis is must in asexual reproduction.
- Papaya plant is dioecious.

Multiple Choice Questions

- External fertilization occurs in majority of (a) algae (b) fungi (c) liverworts (d) mosses. (DUMET 2009)
 - The type of asexual reproduction found in *Hydra* is (a) multiple fission (b) budding (c) sporulation (d) binary fission (e) gemmule formation. (Kerala CET 2009)
 - Monocarpic plant (a) flowers twice in every year (b) bears only one type of flower (c) flowers once in every year (d) dies after flowering once in its life cycle. (Orissa JEE 2009)
 - Exponential growth occurs in (a) yeast (b) asexual reproduction (c) bacteria (d) all of these. (Orissa JEE 2009)
 - A horizontal underground stem is a (a) corm (b) phylloclade (c) rhizome (d) rhizoid. (DUMET 2009)
 - Vegetative propagation in mint occurs by (a) offset (b) rhizome (c) sucker (d) runner. (CBSE PMT 2009)
 - Micropropagation is a technique (a) for production of true plants (b) for production of haploid plant (c) for production of somatic hybrids (d) for production of somaclonal plants. (WB SEE 2010)
 - In double fertilization (a) two male gametes fuse with two eggs (b) one male gamete fuses with the egg and the other fuses with the secondary nucleus (c) one male gamete fuses with the egg and the other fuses with the antipodal (d) one male gamete fuses with the antipodal and the other fuses with the diploid nucleus. (AMU 2010)
 - Synergids are (a) haploid (b) diploid (c) triploid (d) tetraploid. (AMU 2010)
 - Match the items in column I with column II and choose the correct option.

Column I	Column II
A Binary fission	1 Algae
B Zoospore	2 <i>Amoeba</i>
C Conidium	3 <i>Hydra</i>
D Budding	4 <i>Penicillium</i>
E Gemmules	5 Sponge
- (a) A - 1, B - 4, C - 5, D - 3, E - 2 (b) A - 2, B - 1, C - 4, D - 3, E - 5
 (c) A - 1, B - 2, C - 4, D - 3, E - 5 (d) A - 4, B - 1, C - 3, D - 5, E - 2 (Kerala PMT 2010)
- Which one of the following processes results in the formation of clone of bacteria ? (a) Binary fission (b) Conjugation (c) Transformation (d) Transduction. (Karnataka CET 2010)
 - The egg apparatus of angiosperm comprises (a) an egg cell and two antipodals (b) an egg cell and two synergids (c) an egg cell and two polar nuclei (d) an egg cell and the central cell. (DUMET 2010)
 - Breeding of crops with high levels of minerals, vitamins and proteins is called (a) somatic hybridisation (b) biofortification (c) biomagnification (d) micropropagation. (CBSE PMT Prelims 2010)
 - Vegetative propagation in *Pistia* occurs by (a) stolon (b) offset (c) runner (d) sucker. (CBSE PMT Mains 2010)
 - Which of the following is pollinated by water ? (a) *Viola* (b) *Yucca* (c) *Oxalis* (d) *Commelina* (e) *Zostera*. (Kerala PMT 2010)
 - Find out the wrongly matched pair (a) tuber - potato ; (b) rhizome - ginger ; (c) bulbil - Agave (d) leaf buds - banana ; (e) offset - water hyacinth. (Kerala PMT 2010)

- (17) Asexual reproduction in fungi takes place by (a) endospore (b) gametangia (c) exospores (d) conidiospore.
- (18) Nucellar polyembryony is reported in species of (a) *Citrus* (b) *Gossypium* (c) *Trillium* (d) *Brassica*.
(AIPMT (Prelims) 2011)
- (19) Biodiversity of a geographical region represents (a) endangered species found in the region (b) the diversity in the organisms living in the region (c) genetic diversity in the dominant species of the region (d) All of these.
(AIPMT (Mains) 2011)
- (20) Testa of a seed is produced from (a) ovary wall (b) hilum (c) outer integument of ovule (d) funicle.
(J&K CET 2011)
- (21) The ovule in which the funicle, chalaza and micropyle lie in one vertical plane, is called (a) campylotropous (b) amphitropous (c) orthotropous (d) anatropous.
(J&K CET 2011)
- (22) Ovule integument gets transformed into (a) seed (b) fruit wall (c) seed coat (d) cotyledons.
(West Bengal JEE 2011)
- (23) Both autogamy and geitonogamy are prevented in (a) papaya (b) cucumber (c) castor (d) maize.
(CBSE PMT Prelims 2012)
- (24) In general, pollen tube enters the ovule through (a) micropyle (b) chalaza (c) hilum (d) funicle.
(J & K CET 2012)
- (25) Transfer of pollen grain from anther to stigma of another flower of the same plant is called as (a) geitonogamy (b) xenogamy (c) cleistogamy (d) chasmogamy.
(J & K CET 2012)
- (26) The endosperm cells in angiosperms are (a) haploid (b) diploid (c) triploid (d) tetraploid.
(J & K CET 2012)
- (27) The fleshy edible part of an apple is (a) thalamus (b) nucellus (c) ovary (d) endosperm.
(J & K CET 2012)
- (28) Why asexual reproduction is sometimes disadvantageous? (a) It allows animals that do not move around to produce offspring without finding mates (b) It allows an animal to produce many offspring quickly (c) It saves the time and energy of gamete production (d) It produces genetically uniform populations.
(J & K CET 2012)
- (29) Meiosis takes place in (a) Megocyte (b) Gemmule (c) Megaspore (d) Conidia.
(NEET 2013)
- (30) Product of sexual reproduction generally produces (a) Longer viability of seeds (b) Prolonged dormancy (c) New genetic combination leading to variation (d) Large biomass.
(NEET 2013)
- (31) Which one shows isogamy with nonflagellated gametes
(a) *Spirogyra* (b) *Ulothrix* (c) *Ectocarpus* (d) *Sargassum*.
(CBSE 2014)
- (32) Life span of Parrot is (a) 25 yrs (b) 50 yrs (c) 140 yrs (d) 15 yrs.
(Uttarakhand 2014)
- (33) The semi dwarf wheat which was instrumental in increasing wheat production was developed by (a) Alexander Von Humboldt (b) Paul Ehrlich (c) Dr. Kurién (d) Edward Jenner (e) Norman E. Borlaug.
(Kerala PMT 2014)
- (34) *Planaria* possesses high capacity of (a) metamorphosis (b) regeneration (c) alternation of generations (d) bioluminescence.
(AIPMT 2014)
- (35) Which of the following organisms breeds only once in life time?
(a) Bamboo (b) Oysters (c) Pelagic fishes (d) Birds (e) Mammals.
(Kerala 2015)
- (36) Flowers are unisexual in (a) Pea (b) Cucumber (c) China rose (d) Onion.
(CBSE 2015)
- (37) Stock and scion are used in (a) cutting (b) grafting (c) layering (d) micropropagation. (WB JEE 2015)
- (38) Aquatic weed which is popularly called 'killer of Bengal' is
(a) *Erythroxylum* (b) *Elchhornia* (c) *Echinus* (d) *Echidna*.
(EAMCET – Andhra 2016)
- (39) Which one of the following generates new genetic combinations leading to variation
(a) Nucellar polyembryony (b) vegetative reproduction (c) parthenogenesis (d) sexual reproduction.
(NEET-II 2016)
- (40) Which one of the following statements is not correct?
(a) Offspring produced by the asexual reproduction are called clone (b) Microscopic, motile asexual reproductive structures are called zoospores (c) In potato, banana and ginger, the plantlets arise from the internodes present in the modified stem (d) Water hyacinth, growing in the standing water, drains oxygen from water that leads to the death of fishes.
(NEET-II 2016)

- (41) Which is used to maintain genetic traits of a green plant (a) Propagation through seed germination (b) Propagation through vegetative multiplication (c) Generating hybrids through intergeneric pollination (d) Treating seeds with gamma radiations. (AIIMS 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given. One is assertion (A) and one is reason (R). Mark the correct answer as

- (A) If both A and R are true and R is correct explanation of A.
 (B) If both A and R are true but R is not the correct explanation of A.
 (C) If A is true but R is wrong.
 (D) If both A and R are false

- Assertion.** Parthenogenesis is a kind of variation of sexual reproduction.
Reason. In Parthenogenesis, a young one develops from an ovum but without fertilization.
 (A) (B) (C) (D)
- Assertion.** All members of bee society are diploid except the drones.
Reason. Drones are produced parthenogenetically.
 (A) (B) (C) (D)
- Assertion.** The honey bee queen copulates only once in her life time.
Reason. The honey bee queen lays fertilized as well as unfertilized eggs.
 (A) (B) (C) (D)
- Assertion.** In angiosperms, the ovule develops into a seed after fertilization.
Reason. Fertilization is not essential for the development of fruit.
 (A) (B) (C) (D)
- Assertion.** Viviparous animals give better protection to their offsprings.
Reason. They lay their egg in safer places in the environment.
 (A) (B) (C) (D)

ANSWERS

Miscellaneous

- (a) —V (b) —III (c) —II (d) —I (e) —IV
- (a) —gametes (b) —embryo, zygote (c) —oviparous (d) ovules
- (i) —T (ii) —F (iii) —T (iv) —T (v) —T (vi) —F (vii) —T

Multiple Choice Questions

- (1) —a (2) —b (3) —d (4) —b (5) —c (6) —c (7) —a (8) —b (9) —a (10) —b
 (11) —a (12) —b (13) —b (14) —b (15) —e (16) —d (17) —d (18) —a (19) —b (20) —c
 (21) —c (22) —c (23) —a (24) —a (25) —a (26) —c (27) —a (28) —d (29) —a (30) —c
 (31) —a (32) —c (33) —e (34) —b (35) —a (36) —b (37) —b (38) —b (39) —d (40) —c
 (41) —b

Assertion and Reason Type Questions

- (1) —A (2) —A (3) —B (4) —B (5) —C

2

SEXUAL REPRODUCTION IN FLOWERING PLANTS

Sexual reproduction is the process of development of new organisms through the formation and fusion of gametes. Gametes are not directly formed by the sporophytic structures of flowering plants. Instead, they produce spores and then gametophytes. The organs specialised to perform sexual reproduction in angiosperms are flowers. **Flowers** are modified condensed reproductive shoots. All of us are familiar with flowers because they constitute the most beautiful structures of nature being full of variety, shapes, colour and scent. Flowers are being used by humans to express love, affection, happiness, grief and mourning. They are objects of aesthetic, ornamental, social, religious and cultural value. Bees obtain nectar from them and convert it to honey. They have been a source of dyes, scents and perfumes since times immemorial.

Flowers are formed over mature plants in response to hormone induced structural and physiological changes in shoot apices. Shoot apices are transformed into an inflorescence over which floral primordia develop. The primordia grow into floral buds which undergo **anthesis** and form flowers. A typical flower has a broad base or **thalamus** over which are borne 4 whorls of floral leaves viz., **sepals** (calyx), **petals** (corolla), **stamens** (androecium) and **carpels** (gynoecium). The last two represent male and female reproductive structures of flowers. They are called **essential floral organs**. Sepals and petals are **accessory or nonessential floral organs** as they have only supportive role.

Stamen— The male reproductive organ

Stamen is the male reproductive organ or microsporophyll of a flower. It consists of two parts, filament and anther. **Filament** is long and slender stalk. It is attached proximally to thalamus, petal or tepal. Distally it bears an anther. **Anther** is broader knob-like fertile part of the stamen. It consists of generally

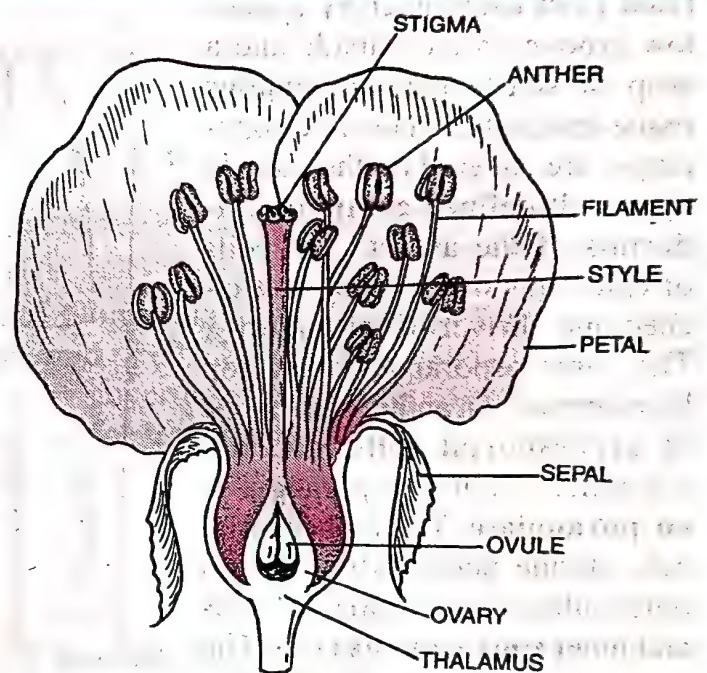


Fig. 2.1. L.S of a flower.

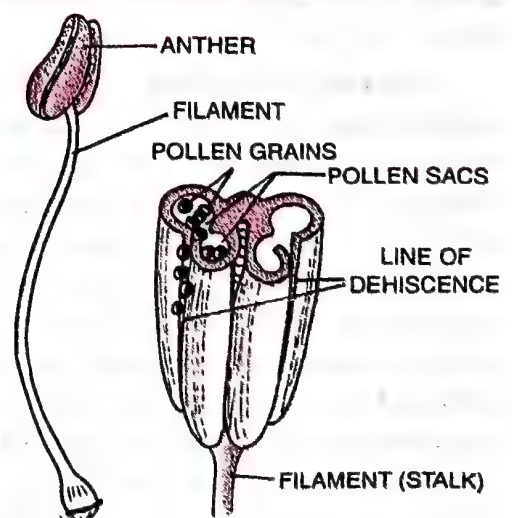


Fig. 2.2. Stamen. A, a typical stamen; B, 3-dimensional cut section of an anther.

two lobes. The two anther lobes are separated in the anterior region by a deep groove but are attached to each other on the back side by a sterile parenchymatous tissue called **connective**. Connective possesses a vascular strand.

(a) Structure of Anther

It is a bilobed tetragonal oblong knoblike fertile part of stamen. Each anther lobe has two chambers. The two chambers of an anther lobe possess long and cylindrical **pollen sacs** or **microsporangia**. Thus a bilobed anther is **tetrasporangiate**. Rarely, an anther lobe has only one microsporangium, e.g., *Wolffia* or there is just one microsporangium per anther, e.g., *Arceuthobium*. The four microsporangia of an anther lie at its four corners. They run parallel to one another. The two microsporangia of an anther lobe are separated from each other by a shallow groove on the outside and a strip of sterile parenchymatous tissue internally.

All the microsporangia are covered on the outside by a well defined **common epidermis** of the anther. The cells of epidermis often become stretched and shrivel off at maturity. The microsporangia develop hypodermally in anther from strips of **archesporial cells**, i.e., development of microsporangia is **eu-sporangiate**. The archesporial cells divide periclinally to form outer subepidermal **parietal cells** and inner **sporogenous cells**. The parietal cells divide further by periclinal walls to produce a 3–5 layered **microsporangial wall** consisting of **endothecium**, **middle layers** and **tapetum**.

Microsporangium. A microsporangium or future pollen sac is a cylindrical sac which appears circular in transverse section. It consists of two parts, outer wall and central homogeneous sporogenous tissue. Microsporangial wall has four types of layers—epidermis (common anther covering), endothecium, 1–3 middle layers and tapetum. The outer three perform the function of protection in the young anther and mechanism of dehiscence in the ripe anther. Both endothecium and tapetum consist of larger cells. In a typical anther the endothelial cells develop fibrous thickenings of α -cellulose on the inner and radial walls and become dead. Because of the presence of fibrous thickenings, the endothecium is also called **fibrous layer**. In the shallow groove present between the two microsporangia of an anther lobe the hypodermal cells lying at the level of endothecium remain thin walled. They constitute the **stomium** or line of dehiscence.

Cells of middle layers shrivel in the mature anther. The tapetal cells enlarge radially and become filled with dense protoplasmic contents as well as nutrients. They either become

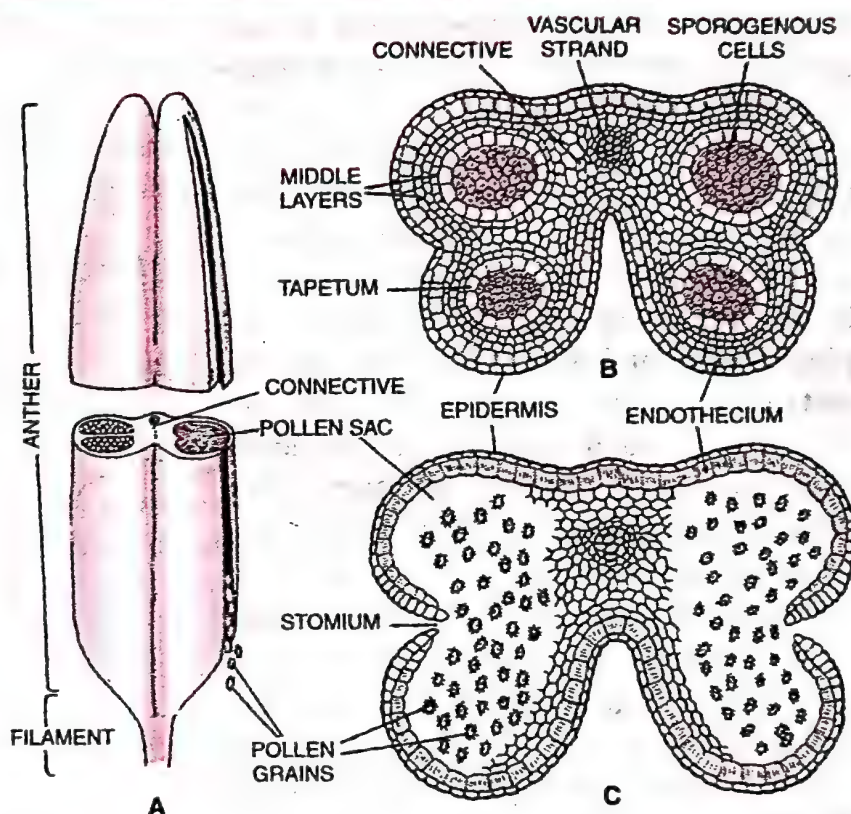


Fig. 2.3. Structure of Anther. A, longitudinally dehiscent anther cut transversely to show pollen sacs and connective. B, T.S. young anther; C, T.S. anther at the time of dehiscence (common or longitudinal type).

multinucleate or their nucleus becomes polyploid due to endoploidy. Tapetum is of two types— **amoeboid** (= invasive, periplasmodium) and **secretory** (= glandular, parietal). In amoeboid type the tapetal cells fuse to form a plasmodium or **periplasmodium** because it passes in between the sporogenous cells to nourish them. The cells of secretory tapetum pass out substances over the sporogenous cells for their growth and differentiation. Ultimately both the types of tapetum degenerate.

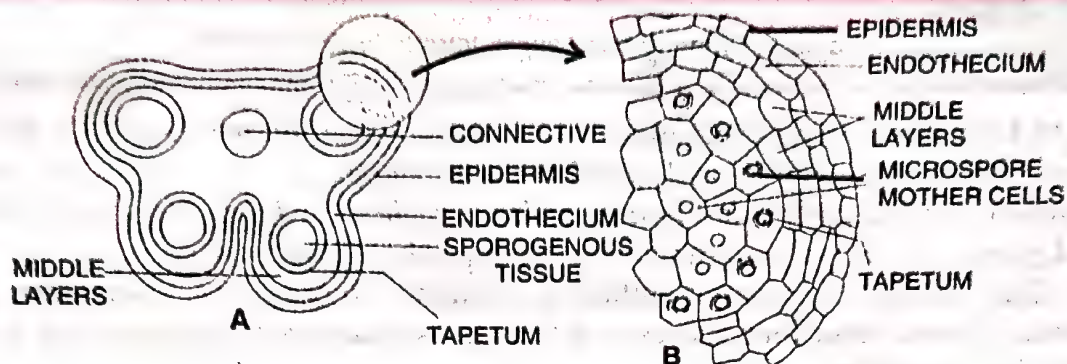


Fig. 2.3 (A). A, T.S. mature anther. B, Part of one microsporangium.

Tapetum has a number of functions : (i) Nourishment of the developing microspore mother cells and pollen grains. (ii) It produces lipid rich Ubisch granules containing sporopollenin for exine formation, pollenkit (oily, sticky covering of lipids and carotenoids) in case of entomophilous pollen grains, special proteins for the pollen grains to recognise compatibility and hormone IAA. (iii) It secretes enzymes like callase responsible for the degradation of callose wall around pollen tetrad.

(b) Microsporogenesis (Development of Pollen grains)

Sporogenous tissue fills the whole interior of a microsporangium. Its cells divide with the growth of anther and increase their number. Ultimately they are transformed into **microspore** or **pollen mother cells (PMC)**. The latter are diploid, that is, they possess two genomes or sets of chromosomes. The microspore mother cells or microsporocytes develop an internal layer of **callose** (β -1, 3 glucan) which breaks the plasmodesmal connections among them. The separated mother cells round off and undergo meiosis to produce tetrads

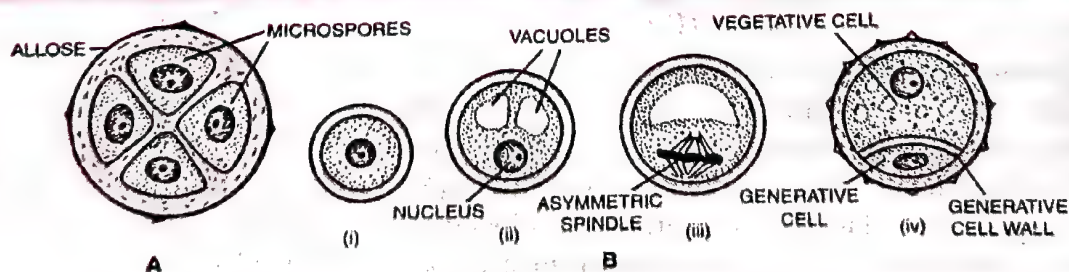


Fig. 2.4. Microsporogenesis. A, a microspore tetrad. B, a microspore maturing into a pollen grain.

of haploid **microspores** or **pollen grains**. The phenomenon is called **microsporogenesis**. The pollen grains of a tetrad grow and separate from one another. Usually the arrangement of microspores in a tetrad is **tetrahedral** (most common type) or **isobilateral**. However, decussate, linear and T-shaped tetrads are also found (Fig. 2.5). In *Aristolochia elegans*, all the five type of tetrads have been recorded. Mostly, all the 4 nuclei in a tetrad remain

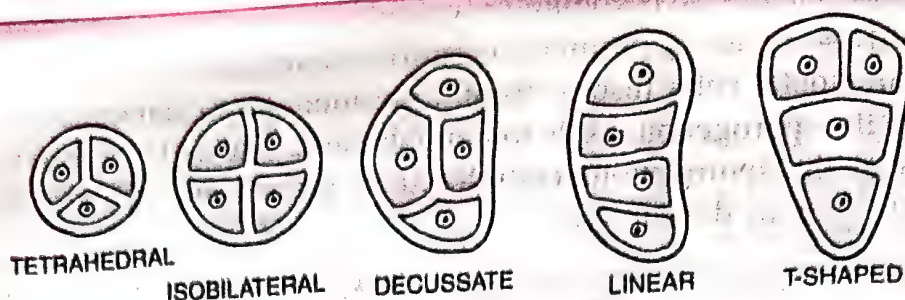


Fig. 2.5. Types of microspore tetrads in *Aristolochia*.

functional to form 4 microspores. However, in *Cyperaceae*, only one functions and therefore, only one microspore instead of 4 is formed by one meiosis. In some cases, all the 4 pollens remain attached forming **compound pollen grains** e.g., *Juncus*, *Jatropha*, *Typha*. In *Calotropis* and related plants all the pollen grains of an anther lobe remain united in a single sac called **pollinium**. Two pollinia of adjacent anthers are attached to produce a **translator**. **Polyspory** is occurrence of more than four spores in a tetrad. As many as 11 microspores are observed in a 'tetrad' in *Cuscuta*.

Dehiscence of Anther

The mature anther dries up. The sterile strip present between the two pollen sacs of each anther lobe disintegrates to form a single cavity. Therefore, the mature anther has only two cavities or **thecae**, with one theca in each anther lobe. Mature anther is therefore, called **ditheous***. With the loss of water the differentially thickened dead cells of endothecium contract from their outer thin walls. The latter become concave. It brings their outer radial walls nearer. As a result the endothecium shortens and ruptures the anther lobe wall in the region of stomium. The line of dehiscence is longitudinal in such cases, e.g., Mustard. Line of dehiscence as well as pollen grains can be observed by placing a finger over the ripe anther. A line of yellowish powdery mass of pollen grains will appear over the finger. The same can be placed over a drop of water taken on a slide and observed under the microscope. The exposed spores are picked by various agencies for pollination. Local degradation of wall occurs in other types of dehiscence like valves in *Barberry*, pores in *Solanum* and irregular rupturing in *Najas*.

(c) Structure of Pollen Grain (Figs. 2.6-8)

It is commonly globular in outline, though several other shapes are also found. The diameter is 25–50 μm . There is a highly resistant wall on the outside and cellular contents inside. Its cytoplasm is rich in starch and unsaturated oils. The latter protect the chromosomes from radiation damage. Pollen grain protoplast is uninucleate in the beginning but at the time of liberation it becomes 2–3 celled. Wall or covering of pollen grain is called **sporoderm**. It has two layers, outer **exine** and inner **intine**. Intine is pecto-cellulosic in nature. At places it contains enzymatic proteins (Knox and Heslop-Harrison, 1971). Exine is made of a highly

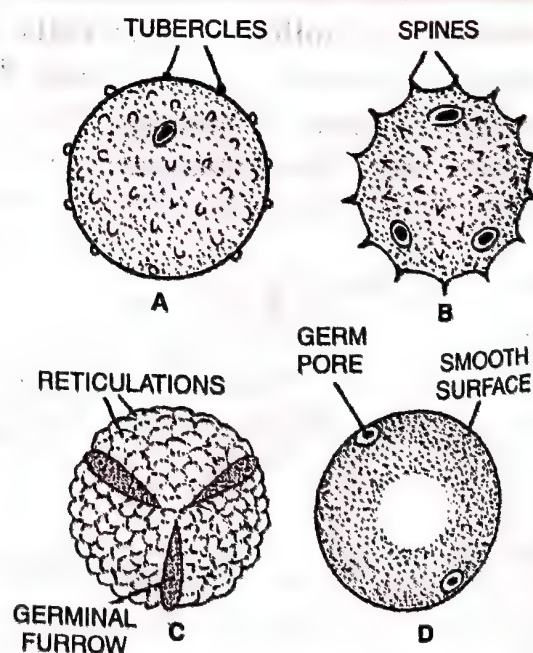


Fig. 2.6. Common pollen grain sculpturing.

*NCERT calls each anther lobe as ditheous as it contains two chambers or theca (= Thecae).

resistant fatty substance called **sporopollenin** (Zelisch, 1932). Sporopollenin is not degraded by any enzyme. It is not affected by high temperature, strong acid or strong alkali. Because of the sporopollenin, pollen grains are well preserved as microfossils. At places, exine possesses proteins for enzymatic and compatibility reactions. Exine is differentiated into outer **ektexine** (sexine) and inner **endexine** (nexine). Ektexine is further made up of an inner continuous **foot layer**, a middle discontinuous **baculate layer** and outermost discontinuous **tectum**. Tectum provides a characteristic sculpturing or designs over the surface of pollen grain, e.g., ridges, tubercles, spines, reticulations. It can help experts to identify the pollen grains and refer them to their family, genus or species. The study of external morphology of mature pollen grains is called **palynology**.

In insect pollinated pollen grains the exine is spiny as well as covered over by a yellowish, viscous sticky and oily layer called **pollenkit**. Pollenkit is made up of lipids and carotenoids. Exine is smooth in anemophilous pollen. At certain places the exine is thin or absent. The areas may have thickened intine or deposition of callose. They are called **germ pores** (if rounded) or **germinal furrows** (if elongated). Pollen grains are generally tricolpate (with three germ pores) in dicots and monocolpate (with single germinal furrow) in monocots.

Pollen Viability. It is the period for which pollen grains retain the ability to germinate. Pollen viability is little in flowers which are pollinated in bud condition. It is 30 minutes in Rice and Wheat. In others the period of viability is long, even months in some members of family rosaceae, leguminosae and solanaceae. It, however, depends upon environmental conditions of temperature and humidity. It is possible to store pollen grains for years in liquid nitrogen (-196°C) in **pollen banks** for later use in plant breeding programmes.

Pollen Allergy. Pollen grains are produced in large number, especially in anemophilous species. They float in air and enter respiratory tracts. Some individuals develop allergy to them, producing respiratory disorders like rhinitis, asthma and bronchitis—**bronchial allergy** (Hay Fever) The major contributor to pollen allergy is Carrot Grass, *Parthenium*. It entered India as contaminant with imported Wheat but has spread in all parts of the country. *Chenopodium*, *Amaranthus*, *Sorghum*, *Ricinus*, *Prosopis*, *Cynodon* are other common sources of pollen allergy. Since different plants produce pollen grains in different seasons, pollen calendars of atmosphere can be scanned and the allergic reaction pinpointed to particular plants.

Pollen Products. The pollen grains especially the ones collected by Bees are being used for a variety of purposes like nature cure, cosmetics

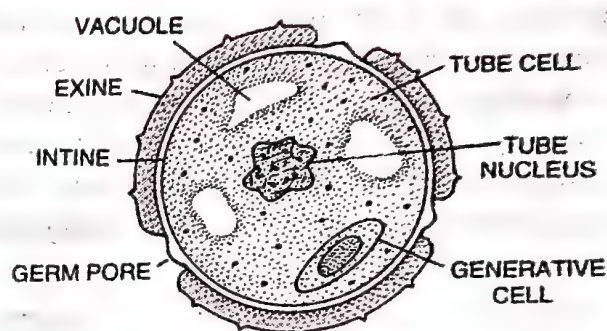


Fig. 2.7. Section of a mature 2 celled pollen grain of an angiosperm.



Fig. 2.8. Pollen Products.

and as food supplements. Pollen grains are believed to be rich in nutrients (Protein 7–26%, carbohydrates 24–48%, fats 0.9–14.5%). They are taken as tablets or syrups to improve health, enhance performance of athletes and race horses.

(d) **Structure and Development of Male Gametophyte** (Microgametogenesis; Fig. 2.9)

Pre-Pollination Development. Pollen grain or microspore is the first cell of male gametophyte and represents **immature male gametophyte**. Development of male gametophyte is **precocious**, that is, it begins inside the microsporangium or pollen sac. When first formed the microspore or young pollen grain has a centrally placed nucleus embedded in dense cytoplasm covered by plasma membrane. It grows in size with the inflow of nutrients. Vacuoles develop and bring about rapid growth of pollen grain. The vacuoles push the pollen grain nucleus to one side near the wall. The protoplast then divides mitotically to form two unequal cells—small **generative cell** and large **tube or vegetative cell**. A layer of callose develops around the generative cell which separates the cell from the pollen grain wall. Later on, callose dissolves and the naked generative cell comes to lie freely in the cytoplasm of the tube cell. The tube cell has a vacuolate cytoplasm which is rich in the food reserve (starch, protein, fat with mostly unsaturated fatty acids) and cell organelles. Its nucleus becomes large and irregular. The generative cell is spindle shaped to spherical in outline with thin dense cytoplasm surrounding a prominent nucleus. In some species the generative cell divides into two nonmotile male gametes prior to the dehiscence of anther and release of the pollen grains. Therefore, at the time of pollination, the pollen grain is either 2-celled (tube cell + generative cell; found in over 60% of flowering plants, mostly dicots) or 3-celled (tube cell + two male gametes).

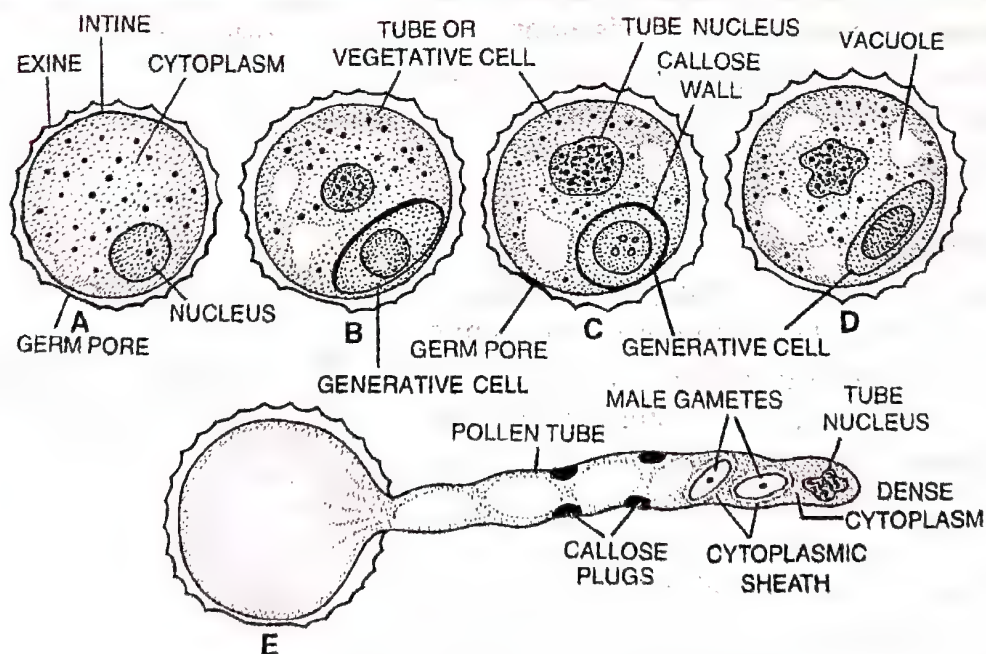


Fig. 2.9. Germination of pollen grain and formation of male gametophyte in an angiosperm.

Post-Pollination Development. On the stigma the compatible pollen grain absorbs water and nutrients from the stigmatic secretion through its germ pores. The tube or vegetative cell enlarges. It comes out of the pollen grain through one of the germ pores or germinal furrows to form a pollen tube. The pollen tube is covered over by intine. It was reported by an Italian mathematician **Amici** (1824) in *Portulaca*. It secretes pectinases and

other hydrolytic enzymes to create a passage for it in the style if the latter is solid. The pollen tube absorbs nourishment from the cells of the style for its growth.

The tube nucleus descends to the tip of the pollen tube. The generative cell (or its products) also passes into it. It soon divides into two nonmotile **male gametes** if it is not already divided. Each male gamete is lenticular to spherical in outline. It has a large nucleus which is surrounded by a thin sheath of cytoplasm. Each male gamete is considered to be one cell. The tube nucleus may degenerate completely.

The pollen tube is glandular, secretory and absorptive. It has (i) Growth zone at tip (cap block) with dense active cytoplasm rich in vesicles. (ii) Nuclear zone containing tube nucleus and male gametes. (iii) Vacuolization zone rich in vacuolated cytoplasm between active and inactive cytoplasm with a series of **callose plugs** to separate older inactive cytoplasm. Pollen tube not only carries male gametes but also secretes hormones and absorb food from style. A pollen grain with pollen tube carrying male gametes represents **mature male gametophyte**. It is **3 celled** (one tube cell + 2 male gametes) and **3 nucleated** structure formed by two mitotic divisions.

Pistil—The female reproductive organ

Gynoecium represents the female component of a flower. It may consist of only one carpel (monocarpellary), two carpels (bicarpellary), three carpels (tricarpellary) or many carpels (multicarpellary). Each carpel represents a megasporophyll. Gynoecium is **apocarpous** (*Gk apo*— away or separate, *karpos*— fruit) if the carpels are free, e.g., *Michelia*, *Ranunculus*. It is **syncarpous** (*Gk syn*— with, *karpos*— fruit) if carpels are fused, e.g., *Hibiscus*, *Papaver* (Poppy). The basal parts of carpels must fuse for syncarpous condition. Parts of styles and stigmas can be free, e.g., *Hibiscus*. In apocarpous condition, the ovaries must be free, though other parts may get fused, e.g., *Oleander*.

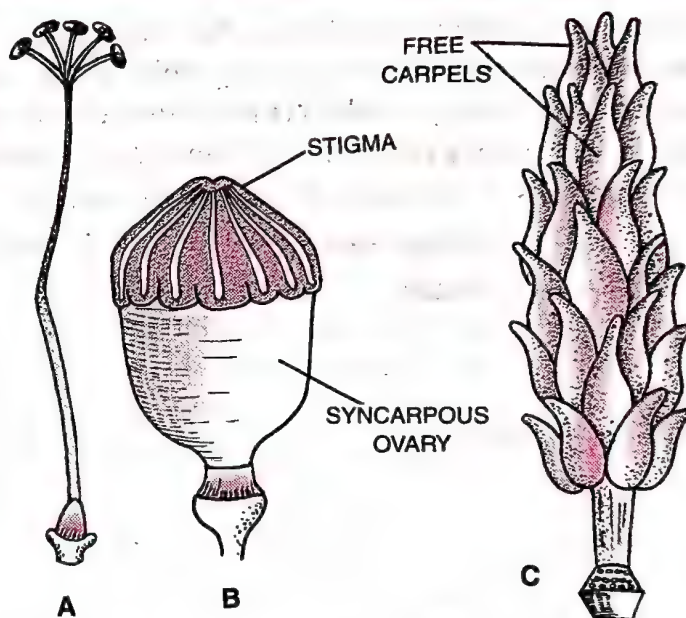


Fig. 2.10. Gynoecium. A, a syncarpous pentacarpellary pistil of *Hibiscus*. B, a syncarpous multicarpellary pistil of *Papaver*. C, an apocarpous multicarpellary gynoecium of *Michelia*.

Differences between Apocarpous and Syncarpous Gynoecium

Apocarpous Gynoecium	Syncarpous Gynoecium
<ol style="list-style-type: none"> 1. The carpels are separate from one another. 2. It is a primitive condition. 3. Ovary is always unilocular. 4. An ovary contains a single placenta. 5. Fruit is aggregate if the number of carpels is more than one. It is a simple in case the carpel is one. 	<ol style="list-style-type: none"> 1. The carpels are fused 2. It is advanced condition. 3. Ovary is unilocular to multilocular. 4. The number of placentae is generally more than one but single placenta occurs in some cases. 5. Fruit is always simple.

The free unit of gynoecium is called **pistil**. A pistil has three parts— stigma, style and ovary. **Stigma** is the terminal receptive part of the pistil which functions as landing platform for the pollen grains. It also determines the compatibility–incompatibility of the pollen grains. **Style** is elongated narrow stalk that connects the ovary with the stigma. **Ovary** is the basal swollen part of the pistil. It has an **ovarian cavity** with one or more chambers or **locules** and ovule bearing parenchymatous cushions called **placentae** (singular placenta). An ovary may have one (e.g., Wheat, Paddy, Mango) to several ovules (e.g., Papaya, Water Melon, Orchids).

(a) **Structure of Ovule.** Ovule is an **integumented megasporangium** found in spermatophytes which develops into seed after fertilisation. An angiospermic ovule is typically an ovoid and whitish structure. It occurs inside ovary where it is attached to a parenchymatous cushion called **placenta** either singly or in a cluster. The ovule is stalked. The stalk is called **funiculus** or **funicle**. The point of attachment of the body of the ovule with the funiculus is known as **hilum**. Depending upon the configuration and orientation of the body of ovule in relation to funiculus, there are six types of ovules— *orthotropous* (atropous, erect), *anatropous* (inverted), *hemitropous* (half inverted), *campylotropous* (body curved), *amphitropous* (both body and embryo sac curved) and *circinotropous* (funiculus coiled around the ovule). In the typical (anatropous) ovule the funiculus is fused with body of the ovule lengthwise beyond the hilum. It gives rise to a longitudinal ridge called **raphe**. Funiculus contains a vascular strand for the supply of nourishment to the ovule.

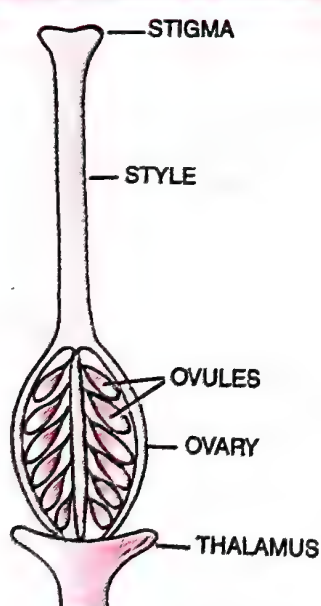


Fig. 2.11 Parts of a pistil.

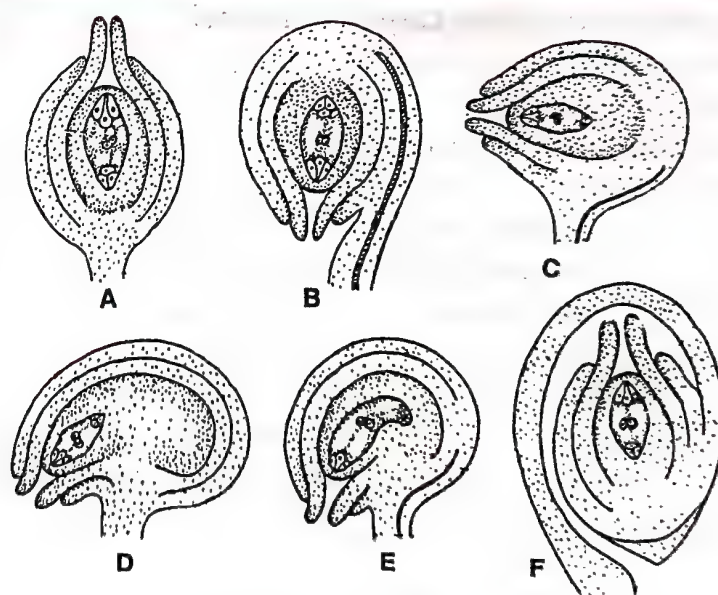


Fig. 2.12. Six different types of ovules in angiosperms.

A, Orthotropous. B, Anatropous. C, Hemitropous.

D, Campylotropous. E, Amphitropous. F, Circinotropous.

The body of the ovule consists of a mass of parenchymatous cells named **nucellus**. It is equivalent to megasporangium. Nucellus may be quite massive (crassinucellate ovule) or thin (tenuinucellate ovule). It is surrounded by one (unitegmic ovule, e.g., higher dicots) or two (bitegmic ovule, e.g., monocots and primitive dicots) multicellular **integuments**. Rarely an ovule may be surrounded by three integuments (tritegmic, e.g., *Asphodelus*) or the integuments are absent (ategmic, e.g., *Santalum*). Free surfaces of nucellus and integuments are covered by cuticle. The integuments leave a narrow pore or passage at one end of the

ovule. It is known as **micropyle**. The place of origin of the integuments usually lies at the opposite end. It is termed as **chalaza**.

Female gametophyte or embryo sac is embedded in the micropylar half of the nucellus.

(b) **Development of Ovule (Megaspороgenesis)**. Ovule develops as primordium and then mound of nucellus over placenta. Initials of integuments develop from its base. They grow and come to surround the nucellus on all sides except at the tip or micropylar region. In the hypodermal region of nucellus towards the micropylar end develops a **primary archesporial cell**. It grows in size and develops a prominent nucleus. The archesporial cell often divides once into outer **primary parietal** or **wall cell** and inner **primary sporogenous cell**. Primary parietal cell may divide one or more times.

The primary sporogenous cell commonly functions directly as diploid **megaspore mother cell** or **megasporocyte**. The megaspore mother cell (MMC) undergoes meiosis and forms a **linear tetrad** of 4 haploid **megaspores**. The process of meiotic formation of haploid megaspores from diploid megaspore mother cell is called **megaspороgenesis**. Commonly the chalazal megaspore remains functional while the other 3 degenerate.

(c) **Development of Female Gametophyte (Megagametogenesis)**. The functional megaspore is the first cell of female gametophyte. The cell enlarges and undergoes three

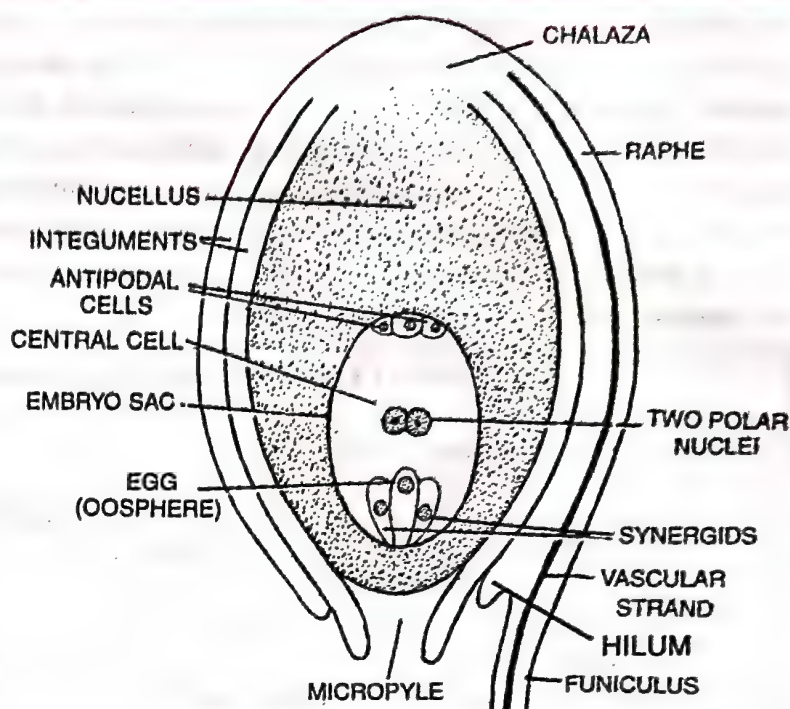


Fig. 2.13. Structure of a typical ovule (anatropous ovule) prior to fertilization.

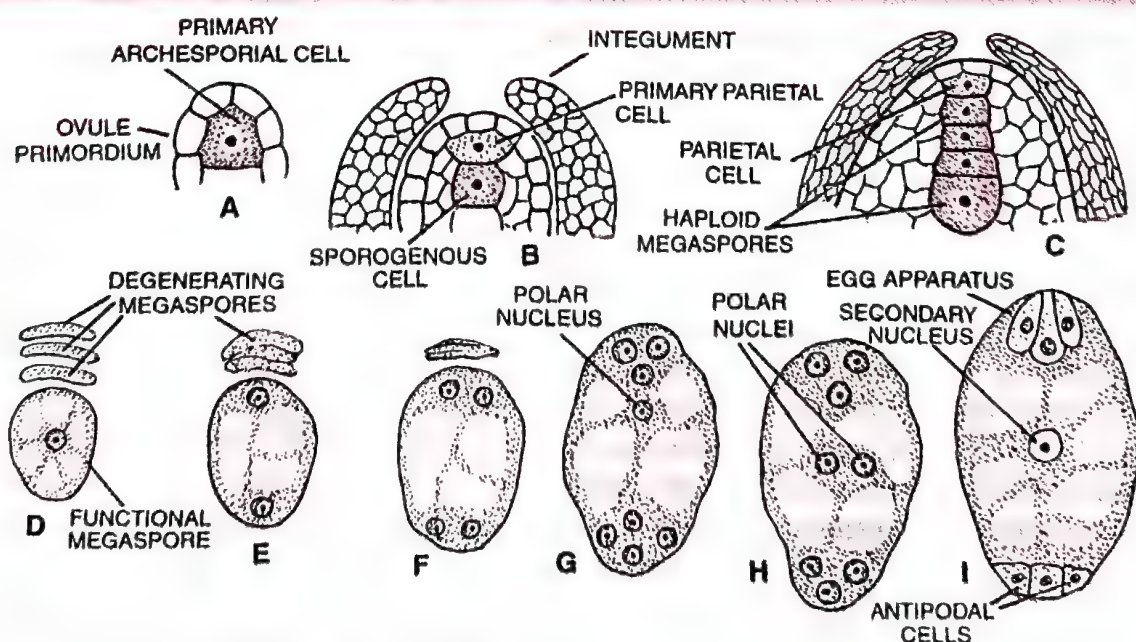


Fig. 2.14. Development of embryo sac.

free nuclear mitotic divisions. The first division produces two nucleate embryo sac. The two nuclei shift to the two ends and divide there twice forming four nucleate and then eight nucleate structure. One nucleus from each side moves to the middle. They are called **polar nuclei**. The remaining three nuclei form cells at the two ends, 3 celled egg apparatus at the micropylar end and three antipodal cells at the chalazal end. The middle binucleate part organises itself into central cell. Embryo sac developed from a single megaspore is called **monosporic**. Maheshwari (1950) has also distinguished bisporic and tetrasporic embryo sacs in which two and four megaspore precursors are involved respectively in the formation of embryo sac.

Differences between Microsporogenesis and Megasporogenesis

<i>Microsporogenesis</i>	<i>Megasporogenesis</i>
1. It is meiotic formation of haploid microspores from diploid microspore mother cell.	1. It is meiotic formation of haploid megaspores from diploid megaspore mother cell.
2. The arrangement of microspores in a tetrad is generally tetrahedral.	2. The arrangement of megaspores in a tetrad is commonly linear.
3. All the four microspores of a spore tetrad are functional.	3. Only one megaspore of a spore tetrad is functional.
4. Microsporogenesis is found inside microsporangium.	4. It is found inside a megasporangium.
5. A large number of microspore mother cells are functional in a microsporangium.	5. Generally a single megaspore mother cell is functional in a megasporangium.

(d) **Structure of Embryo Sac (Female Gametophyte).** In angiosperms, the female gametophyte is called embryo sac. Embryo sac is an oval multicellular haploid structure which is embedded in the nucellus towards micropylar half of the ovule. It is covered over by a thin membrane derived from the parent megaspore wall. The typical and most common type of embryo sac, found in 80% flowering plants is *Polygonum* type (Fig. 2.15). It contains 8 nuclei but 7 cells—3 micropylar, 3 chalazal and one central. It is formed by one meiosis (formation of 4 megaspores from one MMC) and three mitosis (inside functional megaspore). The three micropylar cells are collectively known as **egg apparatus** (equivalent to one archegonium). They are pyriform in outline and are arranged in a triangular fashion. The three cells of egg apparatus have conspicuous common walls towards micropylar half. They separate and become thin towards the central cell. One middle cell is larger and is called **egg** or **oosphere**. It has a central or micropylar vacuole and a nucleus towards the chalazal end. A filiform apparatus may or may not be present. The remaining two cells are called **synergids**, cooperative cells or **help cells**. Each of them bears a filiform apparatus in the micropylar region, a lateral hook, chalazal

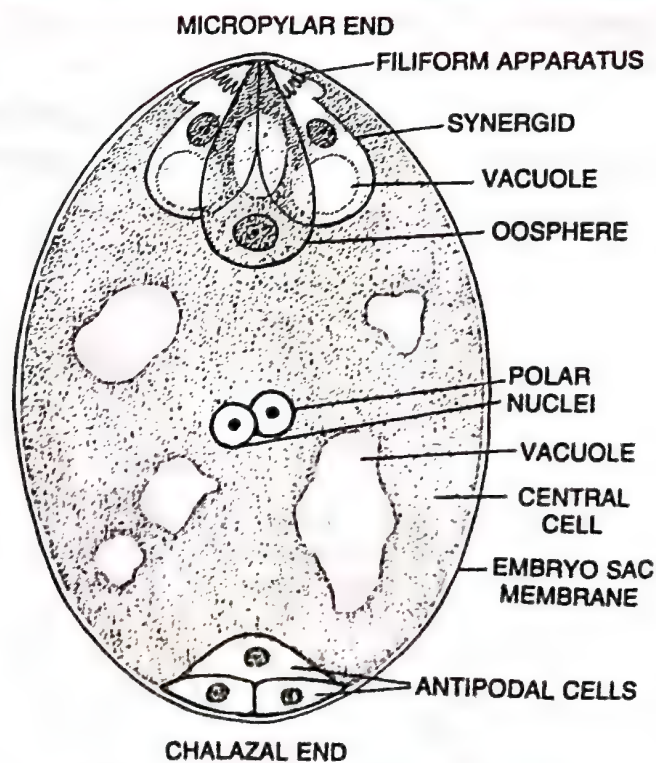


Fig. 2.15. Normal or *Polygonum* type of embryo sac.

vacuole and a central nucleus. A filiform apparatus is a mass of finger like projections of the wall into the cytoplasm. In embryo sac, one synergid degenerates at the time of entry of pollen tube into the embryo sac, whereas, the second one degenerates shortly after the embryo sac has received the pollen tube discharge. All the three cells of the egg apparatus communicate with one another and to the central cell by plasmodesmata. The egg or oosphere represents the single female gamete of the embryo sac. The synergids help in obtaining nourishment from the outer nucellar cells, guide the path of pollen tube by their secretion and function as shock absorbers during the penetration of pollen tube into the embryo sac.

The three chalazal cells of the embryo sac are called **antipodal cells**. They are the vegetative cells of the embryo sac which may degenerate soon or take part in absorbing nourishment from the surrounding nucellar cells. Internally they are connected with the central cell by means of plasmodesmata.

The central cell is the largest cell of the embryo sac. It has a highly vacuolate cytoplasm which is rich in reserve food and Golgi bodies. In the middle, the cell contains two **polar nuclei** which have large nucleoli. The polar nuclei often fuse to form a single diploid **secondary or fusion or definitive nucleus**. Thus all the cells of the embryo sac are haploid except the central cell which is first binucleate and then becomes diploid due to fusion of polar nuclei.

Differences between Male and Female Gametophytes of an Angiosperm

<i>Male Gametophyte</i>	<i>Female Gametophyte</i>
<ol style="list-style-type: none"> 1. It is derived from a pollen grain or microspore. 2. It does not remain permanently embedded inside the microsporangium. 3. It has two phases of growth— pre-pollination and post-pollination. 4. Only pre-pollination growth occurs inside the microsporangium. The remaining occurs over the female reproductive organs. 5. The male gametophyte comes out of the confines of the pollen grain by forming a pollen tube. 6. The male gametophyte is only 3-celled. 7. All the cells of the male gametophyte are functional. The tube cell is required to carry the two male gametes, both of which take part in fertilization. 8. The remains of male gametophyte disintegrate after fertilization. 	<ol style="list-style-type: none"> 1. It is derived from a megaspore. 2. The female gametophyte remains permanently embedded in the megasporangium or nucellus. 3. All the cells are formed in a single phase of growth. 4. The whole growth occurs inside the megasporangium. 5. The female gametophyte remains surrounded by the membrane of the megaspore. 6. The female gametophyte is 7-celled. 7. The antipodal cells do not seem to perform any function except absorption of nourishment from nucellus in certain cases. Out of two synergids only one is required for receiving the pollen tube. 8. After fertilization two new structures are produced both of which show active growth.

POLLINATION

The transfer of pollen grains from the anther to the stigma is called pollination. Pollen grains are immobile. They cannot reach the stigma by themselves. An external agent is required for this. It can be wind, water, animal, gravity or growth contact.

Theophrastus has written on pollination in Date Palm. Kolreuter (1761) recognised the significance of pollination in seed setting and role of insects in pollination.

Pollination is of two types—self pollination and cross pollination (Fig. 2.16).

Self Pollination

It is the transfer of pollen grains from the anther of a flower to the stigma of either the same or genetically similar flower. Accordingly, self pollination is of two types, autogamy and geitonogamy.

1. **Autogamy** (Gk. *autos*—self, *gamos*—marriage). It is a type of self pollination in which an intersexual or perfect flower is pollinated by its own pollen. Autogamy is possible only when anther and stigma are close together and there is synchrony in pollen release and stigma receptivity. Autogamy occurs by three methods.

(a) **Homogamy**. The anthers and stigmas of **chasmogamous** or open flowers are brought together by growth, bending or folding. In *Catharanthus* (= *Vinca*), the growth of style brings the stigma in contact of ripe anthers present on the mouth of corolla tube (Fig. 2.17A). In *Mirabilis* (Four O'Clock), the bending of filaments brings the ripe anthers in contact with stigma (Fig. 2.17B). Potato flowers show curling of style for carrying stigma to ripe anthers (Fig. 2.17 C). When cross pollination fails in Sunflower, the bifid stigma curls back so as to pick the

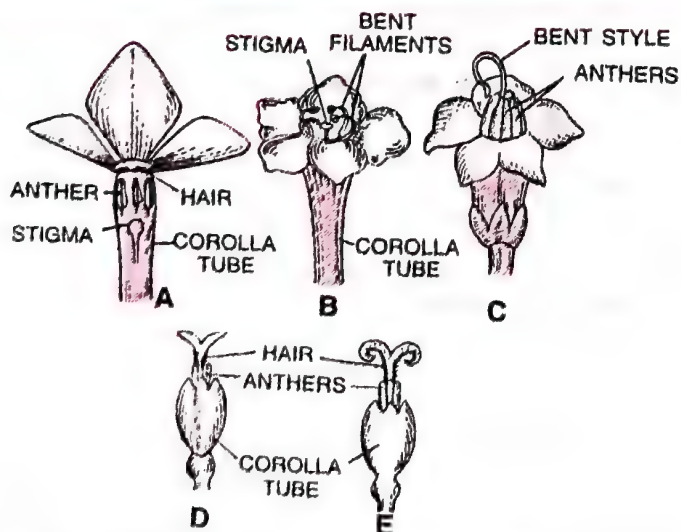


Fig. 2.17. Self pollination through Homogamy and Mechanical Devices. A, Style growing to bring stigma in contact with ripe anthers in *Catharanthus* (= *Vinca*). B, Filaments curving over stigma in *Mirabilis jalapa*. C, Curved style bringing stigma in contact with ripe anthers in Potato. D, Normal position of stigma in Sunflower. E, Stigma curling to receive pollen grain present on brushing hair in Sunflower.

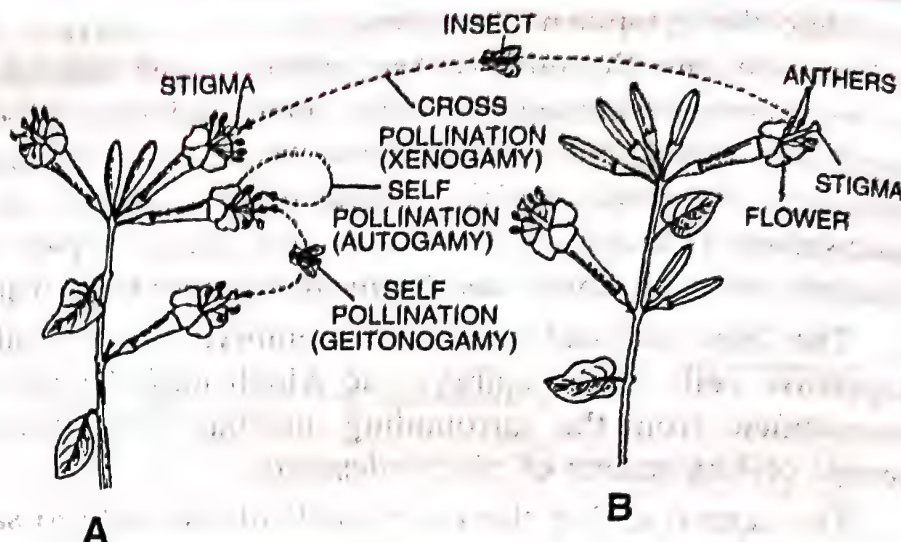


Fig. 2.16. Self and Cross pollination.

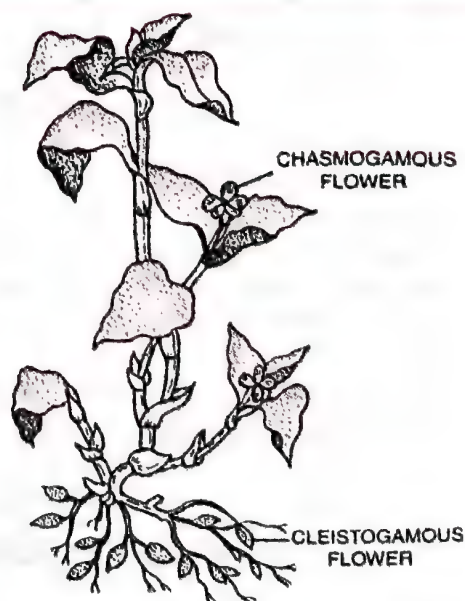


Fig. 2.18 *Commelina* with chasmogamous and cleistogamous flowers.

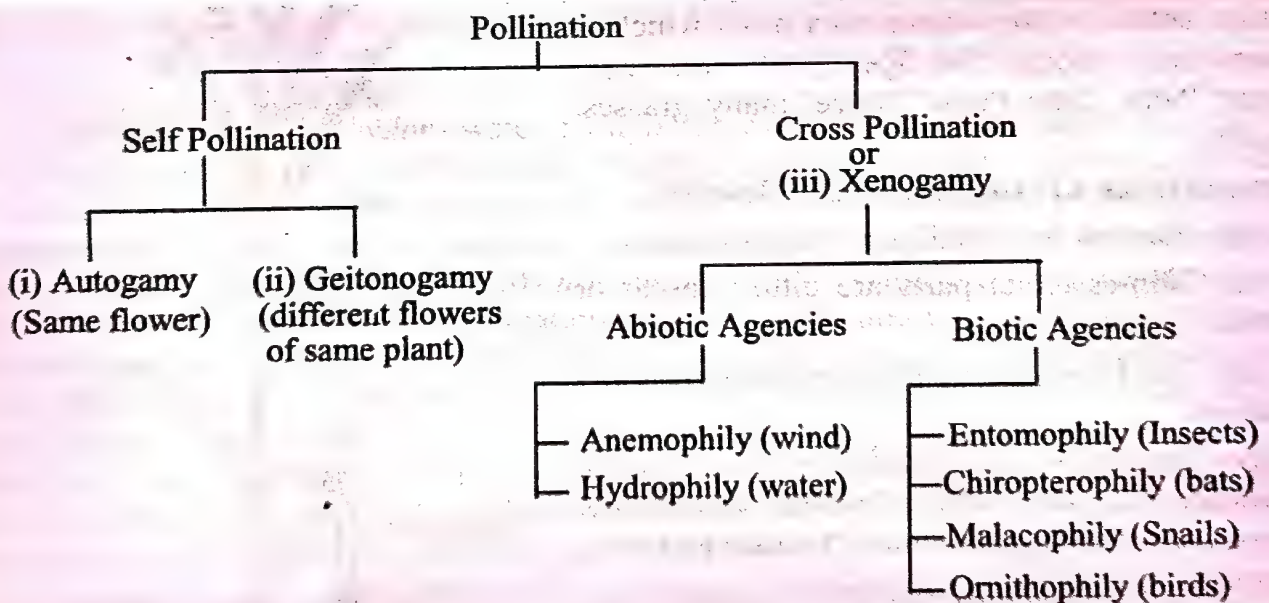
pollen sticking to the surface of style (Fig. 2.17 D, E). It is **fail safe mechanism** of **self pollination**.

(b) **Cleistogamy** (Gk. *kleistos*—closed, *gamos*—marriage; Fig. 2.18). The flowers are intersexual. They remain closed causing self pollination. Cleistogamy occurs late in the flowering season in some plants, e.g., *Commelina bengalensis*, Balsam, *Oxalis*, *Viola*. These plants, therefore, possess both chasmogamous and cleistogamous flowers. In cleistogamous flowers, the anthers dehisce inside closed flowers. Growth of style brings the pollen grains in contact with stigma. Pollination and seed set are assured. Pollinators are not required.

Differences between Chasmogamous and Cleistogamous Flowers	
Chasmogamous Flowers	Cleistogamous Flowers
1. The flowers open, exposing anthers and stigmas.	1. The flowers remain closed so that anthers and stigmas are never exposed.
2. The flowers may undergo self pollination or cross pollination.	2. The flowers undergo only self pollination.
3. A pollinating agency is often required.	3. No external pollinating agency is required.
4. The flowers are often prominent.	4. The flowers are not much distinguishable.

(c) **Bud Pollination**. Anthers and stigmas of intersexual or perfect flowers ripen before the opening of the buds so that self pollination takes place as a rule, e.g., Pea, Wheat, Rice.

2. **Geitonogamy** (Gk. *geiton*—neighbour, *gamos*—marriage). It is a type of pollination in which pollen grains of one flower are transferred to the stigma of another flower belonging to either the same plant or genetically similar plant. In geitonogamy, the flowers often show modifications similar to ones found in xenogamy or cross pollination.



Advantages of Self Pollination

1. It maintains the parental characters or purity of the race indefinitely.
2. Self pollination is used to maintain pure lines for hybridisation experiments.
3. The plant does not need to produce large number of pollen grains.
4. Flowers do not develop devices for attracting insect pollinators.
5. It ensures seed production. Rather it is used as fail safe device for cross-pollinated flowers.

6. Self pollination eliminates some bad recessive characters.

Contrivances (Devices) to Ensure Self Pollination. (1) Flowers are bisexual and both sexes mature at the same time (homogamy). (2) In some cases, flowers are bisexual and cleistogamous, i.e., remain closed. (3) Pollination occurs in bud condition before the opening (anthesis) of flower.

Disadvantages of Self Pollination

1. New useful characters are seldom introduced.
2. Vigour and vitality of the race decreases with prolonged self pollination.
3. Immunity to diseases decreases.
4. Variability and hence adaptability to changed environment are reduced.

Cross Pollination (Xenogamy, Allogamy)

Cross pollination is the transfer of pollen grains from the anther of one flower to the stigma of a genetically different flower. It is also called **xenogamy** (Gk. *xenos*— strange, *gamos*— marriage). The term **allogamy** (Gk. *allos*— other, *gamos*— marriage) includes both geitonogamy and xenogamy. Cross pollination is performed with the help of an external agency. The latter may be **abiotic** (e.g., wind, water) or **biotic** (e.g., insects, birds, bats, snails). Cross pollination is named after the agency that assists it, viz; anemophily (wind pollination), hydrophily (water pollination), entomophily (insect pollination), ornithophily (bird pollination), chiropterophily (bat pollination) and malacophily (snail pollination).

1. **Anemophily** (Gk. *anemos*— wind, *philein*— to love; **Wind Pollination**; Fig. 2.19). It is a mode of cross pollination or transfer of pollen grains from a mature anther to the stigma of a pistil which is accomplished through the agency of wind, e.g., Coconut Palm, Date Palm, Maize, many grasses, *Cannabis*.

Characteristics of Anemophilous Flowers

- (i) Flowers are small and inconspicuous.
- (ii) Non-essential parts are either absent or reduced.
- (iii) The flowers are colourless, odourless and nectarless.
- (iv) In case of unisexual flowers, the male flowers are more abundant. In bisexual flowers, the stamens are generally numerous. Pistil are generally uniovuled.
- (v) Flowers are produced above the foliage, before the appearance of new foliage or placed in hanging position.
- (vi) Both the stigmas and anthers are exserted.
- (vii) Anthers are versatile (Fig. 2.20).
- (viii) In some cases like *Urtica*, the anthers burst suddenly to throw the pollen grains (**gun-powder mechanism**).
- (ix) Pollen grains are light, small and winged or dusty. They can be blown by wind to

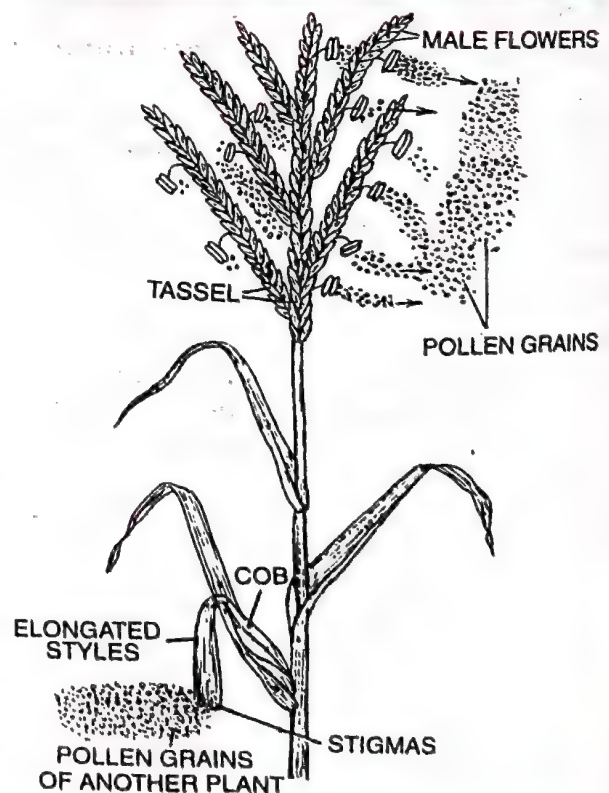


Fig. 2.19. Anemophily in Maize.

distances of upto 1300 km. Winged pollen grains of *Pinus* are found hundreds of kilometres away from the parent plants.

(x) Pollen grains are dry, smooth, nonsticky and unwettable.

(xi) Stigma is hairy, feathery (Fig. 2.19) or branched to catch the wind-borne pollen grains. The large thread-like stigmas and styles of cob of Maize hang in air to catch wind borne pollens.

(xii) Anemophily is highly wasteful as it is nondirectional.

(xiii) Pollen grains are produced in very large number. For example, a single flower of *Cannabis* produces 5,00,000 pollen grains, a tassel of Maize gives rise to 20–25 million pollen grains while a plant of *Mercurialis annua* produces 135 million pollen grains. Consequently, the pollen grains spread over large tracts so that even isolated plants get pollinated. But the large number of the pollen grains cause **bronchial allergy** or depression in many human beings. The phenomenon is also called **hay fever**.

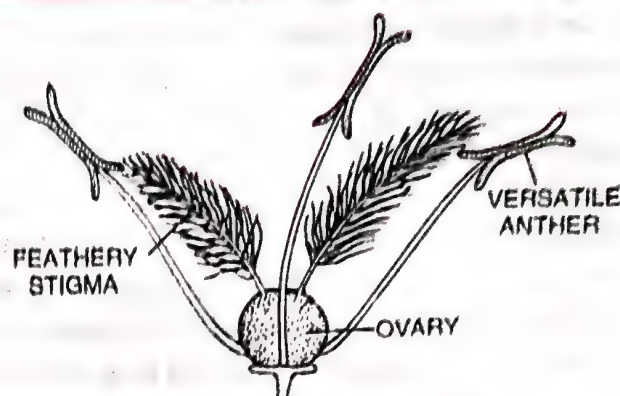


Fig. 2.20. Feathery stigmas and versatile anthers in a flower of Grass.

Differences between Geitonogamy and Xenogamy

Geitonogamy	Xenogamy
1. It is pollination between two flowers of the same plant.	1. It is pollination between two flowers of different plants.
2. The flowers are genetically similar.	2. The flowers are genetically different.
3. It performs self pollination.	3. It performs cross pollination.

2. **Hydrophily** (Gk. *hydor*– water, *philein*– to love ; **Water Pollination**). It is the mode of pollination or transfer of pollen grains from the mature anther of a flower to the stigma of another flower which is accomplished through the agency of water. (i) Flowers are small and inconspicuous. (ii) Perianth and other floral parts are unwettable. (iii) Nectar and odour are absent. (iv) Pollen grains are naked (without exine), thread like for under water pollination and spherical for surface water pollination. They are light and unwettable due to presence of **muclilage cover**. (v) Stigma is long, sticky but unwettable. Hydrophily occurs only in some 30 genera of mostly monocots e.g., *Vallisneria*, *Zostera*, *Ceratophyllum*, etc. In many aquatic plants with emergent flowers, pollination occurs by wind or insects, e.g., Lotus, Water Lily, Water Hyacinth. Hydrophyly is of two types—**hypohydrophily** and **epihydrophily**. Hypohydrophily occurs below the surface of water, e.g., *Zostera*, *Ceratophyllum*. Epihydrophily takes place over the surface of water, e.g., *Vallisneria*.

In *Zostera*, the marine angiosperm (**Sea Grass**), the pollen grains are long ribbon-like (upto 2500 μm) and without exine. They have the same specific gravity as that of water. The pollen grains can, therefore, float below the surface of water. The stigmas are also long. The filamentous pollen grains have great chances to touch the long stigmas and coil around the latter to perform pollination.

Ceratophyllum is a submerged fresh water plant which bears both male and female flowers on the same plant. A male flower has 30–45 stamens. The mature anthers break, rise upwardly and dehisce on the surface. The liberated pollen grains are rounded and without exine. They germinate and sink. While sinking, they come in contact with long and sticky 'swaying stigmas to effect pollination.

Vallisneria (Fig. 2.21) is a submerged dioecious fresh water aquatic plant. The male plants produce a large number of male flowers. The male flowers abscise and rise to the surface where they float. The male flowers have two fertile stamens. Two of their tepals form a boat-shaped structure while the third one functions as a sail. The female plants bear long stalked solitary pistillate flowers. The mature female flowers are brought to the surface of water by the elongation of their stalks. They have large sticky trifold stigmas. While floating, the male flowers are drawn in the depression surrounding each female flower. One anther of a male or staminate flower comes in contact with the stigma of the female flower. The anther bursts and pollination is performed. Pollen grains are covered by mucilage which helps them in sticking to stigma as well as protection from wetting by water. After pollination, the female flower is pulled inside water by the coiling of its stalk.

Zoophily (Gk. *zoon* – animal, *philein* – to love). It is pollination through the agency of animals. The most common type of animal pollinators are insects. Others are birds, bats, snails, human beings, etc. Some primates (e.g., Lemurs), arboreal rodents and reptiles (Gecko Lizard, Garden Lizard) have also been found to accomplish pollination inadvertently. Zoophilous flowers are often adapted to be pollinated by particular type of animals. Bees and butterflies pollinate the maximum number of flowering plants. The two common families pollinated by them are Asteraceae and Lamiaceae (= Labiatae).

3. **Entomophily** (Gk. *entomon* – insect, *philein* – to love ; **Insect Pollination**). It is the most common type of zoophily in which the pollen grains of ripe anthers of one flower are transferred to a mature stigma of another flower through the agency of insects like moths, butterflies, wasps, bees, beetles, etc. The insects visit the flowers for nectar, edible pollen grains or shelter. Bees do pollination in nearly 80% of the flowers. They obtain both nectar and pollen grains from the flowers. Bees have pollen baskets for collecting pollen.

Characteristics of Entomophilous Flowers

Entomophilous flowers are coloured for attracting pollinating insects. Moths visit whitish flowers, butterflies and wasps reddish flowers, bees are attracted towards blue, purple-violet and yellow flowers. Bees use ultraviolet radiations for observation. Red appears black in ultraviolet radiations. Therefore, bees seldom visit red flowers. The various traits of entomophilous flowers are :

- (i) They are showy or brightly coloured.
- (ii) The small flowers become conspicuous by their grouping, e.g., head in Sunflower.
- (iii) Where petals are not conspicuous, other parts become showy, e.g., bracts in *Bougainvillea*, leaves in *Euphorbia pulcherrima*, spathes in aroids, one sepal in *Mussaenda*, stamens in *Mimosa*, *Acacia*, etc.

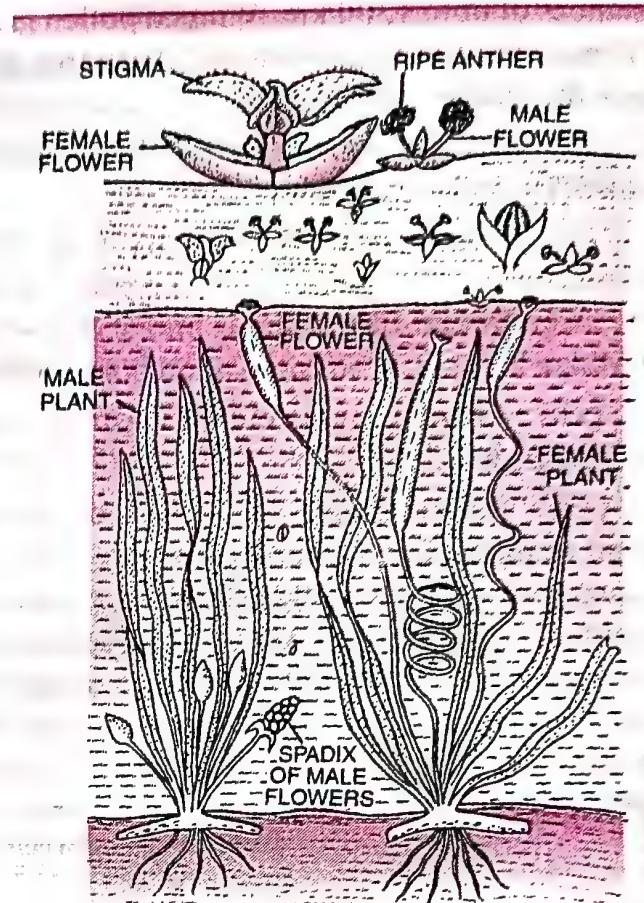


Fig. 2.21. Pollination in *Vallisneria* (Tape Grass).

- (iv) Most insect pollinated flowers have a landing platform.
- (v) Some flowers have structural peculiarities to get pollinated by particular types of insects, e.g., opening of bilabiate personate flowers of Snapdragon (*Antirrhinum*) by particular weight by the pollinator or depth of the corolla tube for different tongued insects.
- (vi) In many cases special markings occur on the petals for guiding the insect to nectar glands. They are called **honey** or **nectar guides** (e.g., *Viola*). The latter often reflect ultra-violet radiations for recognition by bees.
- (vii) The flowers produce an **odour** which may be pleasant (e.g., Jasmine) or foul (e.g., *Aristolochia*, *Arum*, *Rafflesia*). Foul smell attracts flies and beetles. Odour of *Rafflesia* attracts Carrion flies (**Fly trap mechanism**).
- (viii) **Nectar** is secreted for feeding the visiting insects. Nectar glands are placed in such a position that an insect must touch both the anthers and the stigmas.
- (ix) **Edible pollens** are produced by *Rosa*, *Clematis*, *Magnolia*, etc.
- (x) Usually stamens are **inserted** except when they are specialized for attracting insects (e.g., *Mimosa*).
- (xi) The pollen grains are spiny, heavy and surrounded by a yellow oily sticky substance called **pollenkit**.
- (xii) Stigmas are often **inserted** and sticky.
- (xiii) Pollinia of *Calotropis* and related plants cannot be transferred to the stigmatic surface without the help of an insect.
- (xiv) Some flowers provide safe place to insects for laying eggs, e.g., *Yucca*, *Amorphophallus*. The tallest flower belongs to *Amorphophallus* (six feet tall).

Differences between Anemophilous and Entomophilous Flowers

Anemophilous Flowers	Entomophilous Flowers
<ol style="list-style-type: none"> 1. They are small. 2. The flowers are inconspicuous due to the absence of bright colours. 3. They are odourless. 4. The flowers are devoid of nectar and edible pollen. 5. Sepals and petals are either indistinguishable or absent. 6. Anthers are usually exserted. 7. Pollen grains are produced in very large number. 8. Pollen grains are light and unwettable. 9. Pollination is non-directional. 10. Stigmas are exserted. 11. Stigmas are branched or hairy to catch wind-borne pollen grains. 	<ol style="list-style-type: none"> 1. The flowers are either large or if small they are grouped to form a large mass. 2. The flowers are usually gaudy due to the presence of bright colours in corolla, sepals, bracts, etc. 3. Odour is commonly present. 4. The flowers usually possess nectar or edible pollen. 5. Sepals and petals are commonly well developed. 6. Anthers are inserted except when they are specialised to attract insects or prevent self pollination. 7. They are fewer. 8. Pollen grains are heavier and sticky. 9. Pollination is highly specific and directional. 10. They are commonly inserted. 11. Stigmas are usually unbranched and sticky.

Coevolution of Flower and its Pollinator Species

Coevolution is the evolution in two species that interact extensively with one another so that each acts as a major force of natural selection on the other. When one evolves a new feature or modifies itself, the other evolves new adaptations in response of it. This constant mutual feed back modification between the two species is known as coevolution.

The coevolution of the flower and its pollinator species are tightly linked with one another. Flower parts are modified, shaped by mutations and natural selection into a form that enhances pollination. The first group of insects that evolved as pollinators of ancient angiospermic flowers were beetles.

Majority of insect pollinated flowers are beautifully coloured, fragrant, rich in nectar, large in size or if small, they are grouped into an inflorescence to make them conspicuous. To sustain animal visits, flowers have to provide rewards to the animals. Nectar, pollen grains, shelter and edible floral parts and young seeds are the usual **floral rewards for pollinators** and juicy and nutritious fruits for **seed dispersers** so that insects/animals regularly visit them to feed or take shelter. For harvesting the rewards from the flower, the animal visitor comes in contact with the anthers and the stigmas of the flower. The sticky pollens of insect pollinated flowers, get adhered to the body of pollinator. When this pollinator carrying pollen on its body come in contact with the stigma, it brings about pollination.

Flowers pollinated by animals can be grouped into three categories depending upon the benefits (rewards) which they provide to the pollinators.

(i) *Food providing flowers* (e.g., *Salvia* and bees, Humming birds and *Bignonia*, Sun birds and *Streptocarpus*). (ii) *Sex providing flowers* (*Ophrys* and *Colpa* wasp) (iii) *Nursery providing flowers* (e.g., *Yucca* and yucca moth; Fig and wasp).

Special Adaptations in Entomophilous Flowers

(i) Some plants have special adaptations for the insect visitor to help in cross pollination. In *Salvia* a **turn-pipe** or **lever-mechanism** operates to promote cross pollination. *Salvia* (Fig. 2.22) is pollinated by bees. It has protandrous flowers with bilipped corolla. The lower lip functions as a landing platform for the insect. Each stamen has long connective which bears a fertile anther lobe at the upper end and sterile plate-like anther lobe at the lower end. The two sterile anther plates lie side by side and block the path of the insect. As the insect moves inward a young flower in search

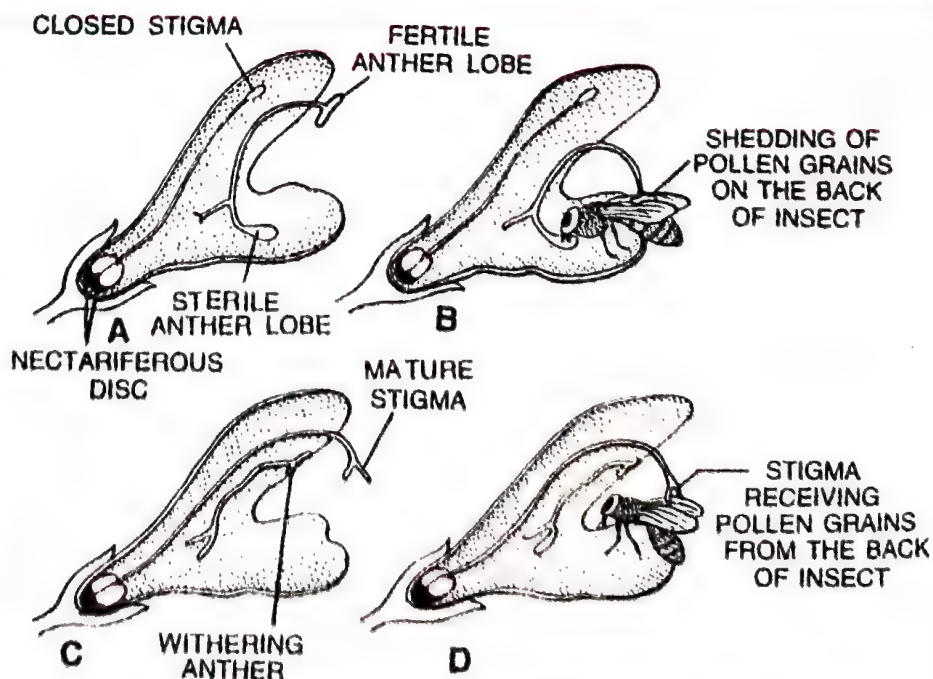


Fig. 2.22. Pollination in *Salvia*. A, flower with mature anthers, closed stigma and short style. B, shedding of pollen grains on the back of entering insect. C, flower with mature stigma and withering anthers. D, stigma receiving pollen grains from the back of entering insect.

A **pollinator** is the agent (wind, animal, water) that moves the pollen. **Pollenizer** is the plant that provides the pollen.

of nectar, its head pushes the sterile anther plates and forces the fertile anther lobes to strike against its back. In older flower the style brings the stigma in such a position that it brushes against the back of the insect and collects pollen grains brought by the insect from a young flower.

(ii) There is a mutual dependence between Fig (*Ficus carica*) and its pollinating agent, female gall wasp *Blastophaga*. Hypanthodia of the plant possess gall flowers for feeding the grubs of the wasp. The early life of wasp is passed inside the hypanthodium. The young wasp coming out of the hypanthodium having mature male flowers drops the pollen inside another hypanthodium having mature female flowers (trap door mechanism). It deposits its eggs in gall flowers.

(iii) *Pronuba* (= *Tageticula*) *yuccasella* is a moth which deposits its eggs in the ovary of *Yucca* flower. Simultaneously, it collects pollen and deposits the same in the hollow of stigma to effect pollination.

(iv) In several species of the orchid like *Ophrys speculum* the shape, colour, markings and odour of the flowers is like the female moth *Colpa*. The *Ophrys* employs **sexual deceit** to get pollination done by the *Colpa*. The male moth matures earlier than the female. It mistakes the *Ophrys* flower for female moth and tries to copulate (**pseudocopulation**). In this attempt, it pollinates the flowers.

4. **Ornithophily** (Gk. *ornis*— bird, *philein*— to love). *It is the mode of allogamy performed by birds*. Only a few types of birds are specialised for this. They usually have small size and long beaks. Two common types of tropical pollinating birds are **sun birds** (Afro-Asia) and **humming birds** (America). Humming birds perform pollination while hovering over the flowers. Sun birds alight over the shoots supporting flowers or occasionally rest over the flowers. Some other pollinating birds are Crow, Bulbil, Parrot and Meynah. Ornithophilous plants are very few as compared to entomophilous plants. Only about 100 species of Australian plants are ornithophilous. Common bird pollinated plants are *Bombax* (Red Silk Cotton), *Erythrina* (Coral Tree), *Callistemon** (Bottle Brush), *Butea monosperma*, *Bignonia*, *Lobelia*, *Agave*, *Grevillea*, etc.

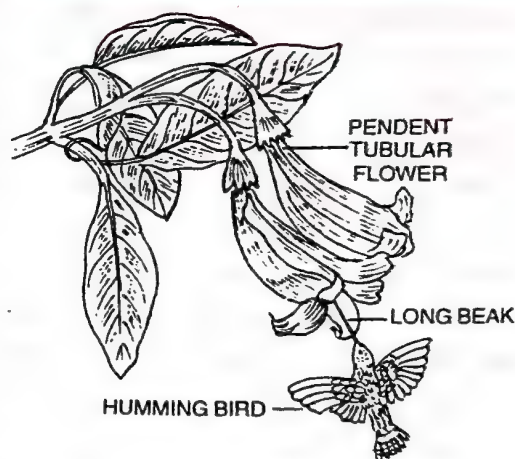


Fig. 2.23. A humming bird collecting nectar from *Bignonia capreolata* flowers thereby pollinating them.

Characteristics of bird pollinated flowers

(i) The ornithophilous flowers secrete abundant watery nectar or have edible parts. (ii) The nectar is secreted in such abundance that drops of it can be brought down by shaking branches of *Grevillea* and *Erythrina*. Nectar is mainly made of sugar. A humming bird may suck nectar in a single day in such quantity as to have sugar equivalent to half of its body weight. (iii) Ornithophilous flowers are usually brightly coloured— red, orange, yellow or blue. (iv) The floral parts are commonly leathery. In some cases, the corolla is funnel-shaped. (v) Scent is often absent.

5. **Chiropterophily** (Gk. *cheir*— hand, *pteros*— wing, *philein*— to love). *It is cross pollination performed by bats*. Bats are nocturnal flying mammals which can transport pollen over long distance, sometimes over 30 km.

*Also pollinated by insects.

Characteristics of Chiropterophilous flowers

Chiropterophilous flowers are dull-coloured with strong fermenting or fruity odour, abundant nectar and pollen grains. Chiropterophilous flowers secrete even more abundant nectar than the ornithophilous flowers. Pollen grains are also produced in more abundance. Baobab Tree (*Adansonia*) has 1500–2000 stamens per flower. The flowers are large and stout. Common examples of chiropterophilous plants are *Kigelia pinnata* (Sausage Tree), *Adansonia* (Baobab Tree), *Anthocephalus* (Kadam Tree) and *Bauhinia megalandra*.

6. **Malacophily** (Gk. *malakos*– soft, *philein*– to love). Snails perform pollination in *Arisaema* (Snake or Cobra Plant) and some arum lilies.

7. **Artificial Pollination** (Anthophily). In all breeding programmes, the plants are hand pollinated to ensure cross pollination between selected varieties. Date Palm has been under artificial pollination since times immemorial.

Outbreeding Devices or Contrivances to Ensure Cross Pollination

(i) **Dicliny** (Unisexuality). Flowers are unisexual so that self pollination is not possible. The plants may be monoecious (bearing both male and female flowers, e.g., Maize) or dioecious (bearing male and female flowers on different plants, e.g., Mulberry, Papaya).

(ii) **Dichogamy**. Anthers and stigmas mature at different times in a bisexual flower so as to prevent self pollination. (a) **Protandry** (Gk. *protos*– first, *andros*– male). Anthers mature earlier than stigma of the same flower. Their pollen grains become available to stigmas of the older flowers, e.g., Sunflower, *Salvia*. (b) **Protogyny** (Gk. *protos*– first, *gyne*– female). Stigmas mature earlier so that they get pollinated before the anthers of the same flower develop pollen grains, e.g., *Mirabilis jalapa* (Four O'Clock), *Gloriosa*, *Plantago*.

(iii) **Prepotency**. Pollen grains of another flower germinate more rapidly over the stigma than the pollen grains of the same flower, e.g., Apple, Grape.

(iv) **Self Sterility** (Self Incompatibility). Pollen grains of a flower do not germinate on the stigma of the same flower due to presence of similar self sterile gene (S_1S_3 in pistil and S_1 or S_3 in pollen grain), e.g., Tobacco, Potato, Crucifers.

(v) **Heterostyly**. There are 2 or 3 types of flowers with different heights of styles (and stamens). (a) **Diheterostyly** (Dimorphic Heterostyly). There are two types of flowers, **pin eyed** (long style and short stamens) and **thrum eyed** (short style and long stamens), e.g., *Primula* (Primrose), Jasmine. (b) **Triheterostyly** (Trimorphic Heterostyly or tristily). There are three types of flowers with different heights of styles (long, medium and short) and stamens (medium and short, long and short, and long and medium), e.g., *Lythrum*. Pollination occurs between anthers and stigmas of the same height present in different flowers (Fig. 2.24).

(vi) **Herkogamy**. It is a mechanical device to prevent self pollination and promote cross pollination. (a) Extrorse dehiscence of anthers. (b) In Pansy, stigma lies inside a flap while in *Kalmia* the anthers occur inside

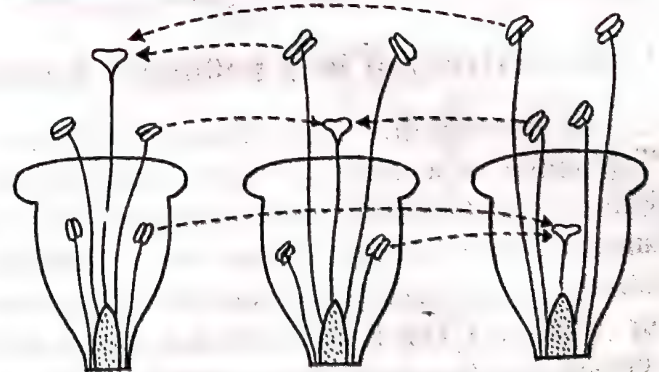


Fig. 2.24. Tristyly. A, Flower with long style, medium and short stamens. B, Flower with medium style and long and short stamens. C, Flower with short style, medium and long stamens.

corolla pocket. (c) In *Cypripedium*, stigmas lie on the route of insect entry while anthers occur near the exit. (d) In *Calotropis* and orchids, pollen grains occur in pollinia which can be lifted by insects only. (e) *Aristolochia* has foul smelling **pit fall** protogynous flowers where the insect gets entrapped and can come out only when the anthers mature.

Differences between Self Pollination and Cross Pollination

Self Pollination	Cross Pollination
<ol style="list-style-type: none"> 1. It is the transfer of pollen grains from anthers to the stigma of either the same or genetically similar flower. 2. Both the anthers and stigmas mature simultaneously. 3. Self pollination can occur even in closed flower. 4. External agency is not required for self pollination, except in case of geitonogamy. 5. Self pollination is economical for the plant. 6. The plants ultimately become homozygous. 7. Self pollination produces pure lines. 8. Self pollination cannot eliminate useless or harmful characters. 9. Highly useful characters are preserved by self pollination. 10. Adaptability to changed environment is absent as self pollination does not produce variability. 11. Immunity of the race towards disease falls with time. 12. Yield of the plant falls with time. 13. It does not help in producing new races, varieties and species. 	<ol style="list-style-type: none"> 1. Cross pollination involves the transfer of pollen from anther of one flower to the stigma of a genetically different flower. 2. The anthers and stigmas mature at different times. 3. It occurs only when the flowers are open. 4. An external agent is essential for carrying the pollen grains from anthers to the stigma. 5. Cross pollination is not economical as the plant has to produce a lot of pollen grains, nectar, scent, bright colour, etc. 6. The plants remain heterozygous. 7. It gives rise to offspring having variations among themselves. 8. Cross pollination dilutes or eliminates the useless and harmful characters. 9. Cross pollination is unable to preserve all the highly useful characters since they tend to get diluted. 10. Plants are better adapted to changed environment and struggle for existence due to introduction of variations. 11. Immunity of the race towards diseases is usually maintained. 12. Yield of the plant does not fall below an average. 13. Cross pollination is a mechanism of producing new races, varieties and even species.

Importance of Cross Pollination

Advantages

1. A number of plants are **self-sterile**, that is, the pollen grains cannot complete growth on the stigma of the same flower due to mutual inhibition or incompatibility, e.g., many crucifers, solanaceous plants. Several plants are **prepotent**, that is, pollen grains of another flower germinate more readily and rapidly over the stigma than the pollen grains of the same flower, e.g., Grape, Apple. Such plants of economic interest give higher yield only if their biotic pollinators like bees are available alongwith plants of different varieties or descent though every other input like adequate irrigation, fertilizers or cultural care might have been already provided, e.g., Sunflower, Safflower, Mustard, Cucurbits, Almond, Cloves, Apple, Pear and related pomaceous plants.

2. Cross pollination introduces genetic recombinations and hence variations in the progeny.

3. Cross pollination increases the **adaptability** of the offspring towards changes in the environment.
4. It makes the organisms better fitted in the struggle for existence.
5. The plants produced through cross pollination are more resistant to diseases.
6. The seeds produced are usually larger and the offspring have characters better than the parents due to the phenomenon of **hybrid vigour**.
7. New and more useful varieties can be produced through cross pollination.
8. The defective characters of the race are eliminated and replaced by better characters.
9. Yield never falls below an average minimum.

Disadvantages

1. It is highly wasteful because plants have to produce a larger number of pollen grains and other accessory structures in order to suit the various pollinating agencies.
2. A factor of chance is always involved in cross pollination.
3. It is less economical.
4. Some undesirable characters may creep in the race.
5. The very good characters of the race are likely to be spoiled.

Pollen-Pistil Interaction

Pollen-pistil interaction is the group of events that occur from the time of pollen deposition over the stigma to the time of pollen tube entry into ovule. It is a dynamic process which has checks at several places for promotion or inhibition of pollen growth. Knowledge of pollen-pistil interaction is helpful to plant breeders in manipulating pollen growth even in incompatible cases. Pollen growth can be observed by dusting pollen (e.g., Pea, Chickpea, *Crotalaria*, Balsam, *Vinca*) on drop of 10% sugar solution. Within 15–30 minutes pollen tubes will be observed to come out of the pollen grains.

Pollen-pistil interaction is a safety measure to ensure that illegitimate crossings do not occur. Pollen grains of a number of plants may settle over a stigma. Only the right pollen belonging to same species would germinate while others fail to do so. Compatibility and incompatibility of the pollen-pistil is determined by special proteins. The compatible pollens are able to absorb water and nutrients from the surface of the stigma. They germinate and produce pollen tubes. Pollen tubes grow into the style. Their growth and path through the style are also determined by specific chemicals.

Significance of Pollination

1. Pollination is a means of taking the male gametophyte for its growth near the female gametophyte.
2. Pollen-pistil interaction determines the suitability of pollen for carrying out the process of sexual reproduction.
3. It has freed the seed plants from the dependance on external water during fertilization.
4. It can be manipulated to produce pure lines as well as desired varieties.

FERTILIZATION

The fusion of male and female gametes is called **fertilization**. In seed plants the male gametes are brought to the egg containing female gametophyte by a pollen tube (Strasburger, 1884). The phenomenon is called **siphonogamy**. A large number of pollen grains (several times more than the number of ovules) come to germinate over the stigma. A pollen grain

does not pass down the stigma. Only its pollen tube does so. The pollen tube eats its way through the solid part of the stigma and style by secreting pectinases and hydrolytic enzymes. Pollen tube travels intercellularly and **chemotropically** along the concentration gradient of calcium - boron - inositol sugar complex. A small copper containing protein *chemocyanin* is also involved in some cases.

Initial growth of the pollen tube takes place on expenditure of food present in the pollen grain. Pollen tube formation seems to be stimulated by factors present in the stigmatic secretion. For further growth the pollen tube obtains its nourishment from the interior of stigma and style. The contents of the pollen grains shift into pollen tube with the tube or vegetative nucleus moving to its tip followed by the two gametes. Further growth of the pollen tube occurs only towards its tip. Depending upon the length of the style and passage inside the ovary, the pollen tube may reach a length of a few millimetres to 45 cm in Maize.

Style may be hollow or solid. Hollow style has a canal lined by special large cells. Solid style has a special tissue of pectinised thick walls known as **transmitting or conducting tissue**. The pollen tube travels along the lining of canal in hollow style drawing nourishment from its living cells. In solid style the pollen tube grows through transmitting tissue by separating their cells through secretion of pectinases. The food is absorbed by diffusion.

Mode of Entry of Pollen Tube in the Ovule.

In the ovary the growth of the pollen tube is directed by another tissue called **obturator**. The pollen tube enters the ovule, either through its micropyle (**porogamy**, e.g., Lily), chalaza (**chalazogamy**, e.g., *Casuarina*, *Juglans*) or the sides after piercing through the integuments or funicle (**mesogamy**, e.g., *Cucurbita*, *Populus*). Porogamy is the most common.

In the ovule the pollen tube is attracted by secretions of synergids. Usually the pollen tube enters the embryo sac by passing into one of the two synergids. The impact destroys that synergid. The pollen tube also breaks open to release its contents. Out of the two male gametes one fuses with egg or oosphere to perform **generative fertilization**. Generative fertilization is also called **syngamy** or true

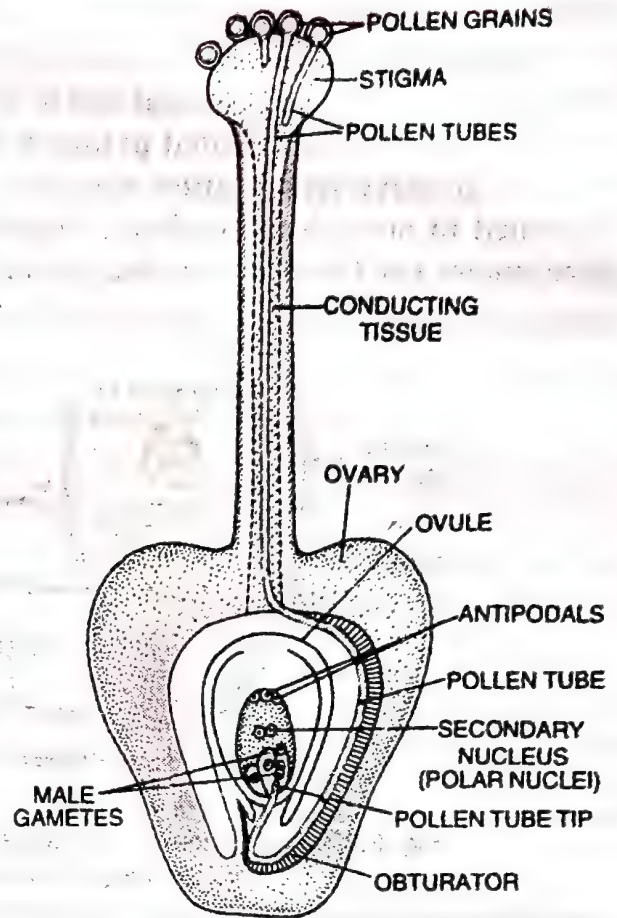


Fig. 2.25. Fertilization in an angiosperm through porogamy.

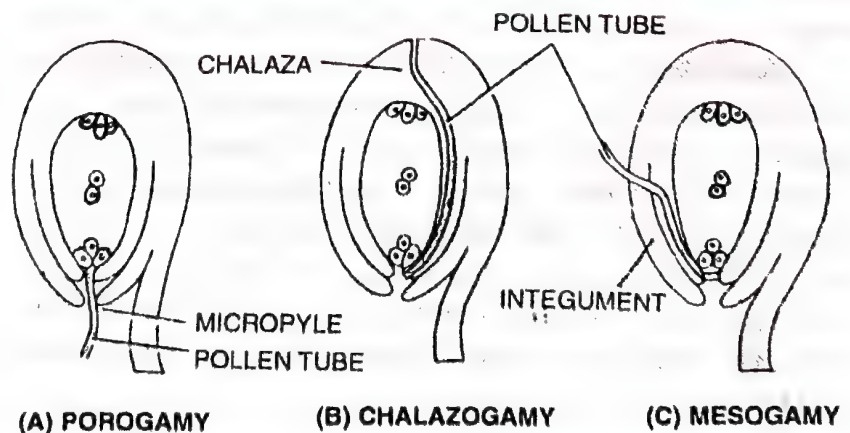


Fig. 2.26. Three modes of entry of pollen tube into the ovule.

fertilization. It gives rise to a diploid zygote or oospore. Soon after, the vacuole and plasmodesmal connections of the egg degenerate. It now becomes ready to produce the embryo.

The nucleus of the second male gamete fuses with the two haploid polar nuclei or diploid secondary nucleus of the central cell to form a triploid **primary endosperm nucleus (PEN)**. The central cell is now called **primary endosperm cell (PEC)**. This second fertilization is called **vegetative fertilization** since as a consequence of it a vegetative or nutritive tissue is formed to nourish the embryo. Vegetative fertilization is also called **triple fusion** since three nuclei get fused, two polar nuclei and one male gamete.

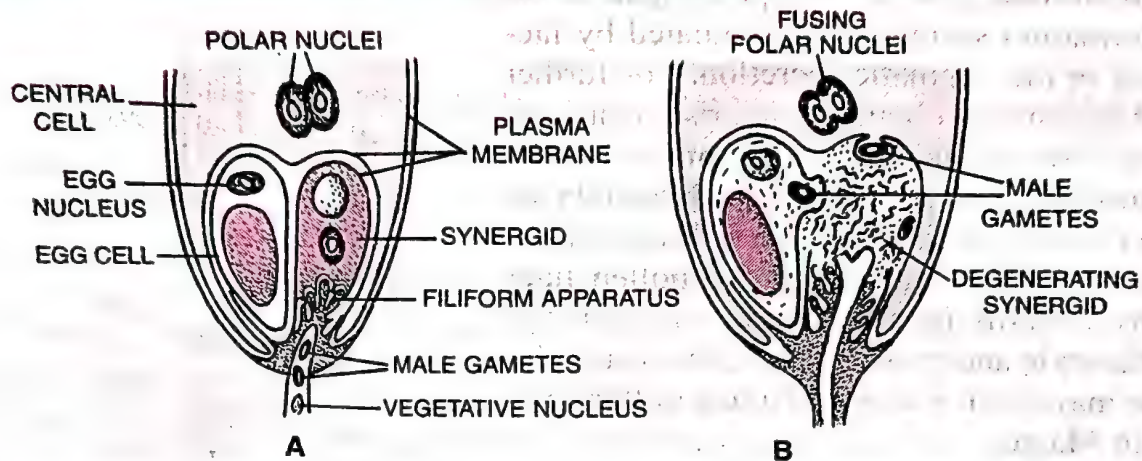


Fig. 2.27. Fertilization. A, egg apparatus showing entry of pollen tube into synergids. B, discharge of male gametes and their movements.

In angiosperms or flowering plants two acts of fertilization occur in the same embryo sac, one generative and other vegetative. The phenomenon is called **double fertilization**.

Double Fertilization

Double fertilization is the fusion of two male gametes brought by a pollen tube to two different cells of the same female gametophyte in order to produce two different structures. It is found only in angiosperms where it was first discovered by Nawaschin in 1898 in *Fritillaria* and *Lilium*. In angiosperms the pollen tube bursts open in one of the two synergids to release the two male gametes. One male gamete fuses with the egg or oosphere to form a diploid zygote or oospore. It is called **generative fertilization**. The second male gamete descends down and fuses with the diploid secondary nucleus of the central cell to form a triploid primary endosperm cell. It is known as **vegetative fertilization**.

Significance

1. In angiosperms the growth of the female gametophyte or embryo sac stops at the 8-nucleate or 7-celled stage. The second act of fertilization, called vegetative fertilization, provides a stimulus to one of its cells to resume growth and form a nutritive tissue.

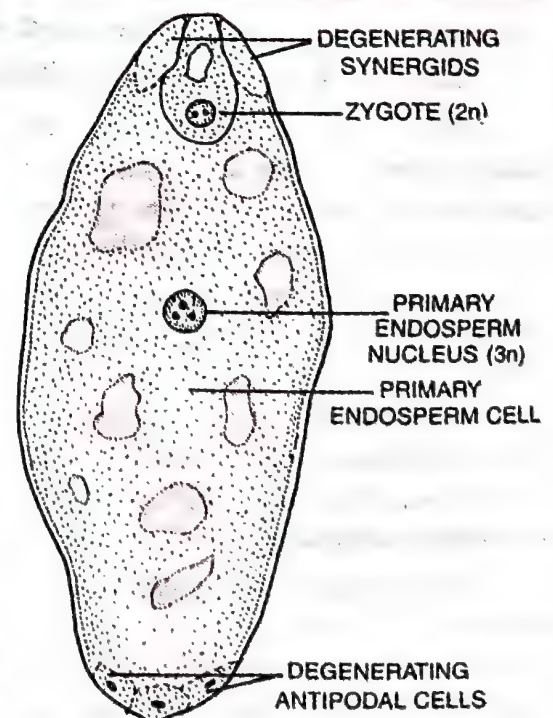


Fig. 2.28. Embryo sac soon after double fertilization.

2. Double fertilization ensures that the nutritive tissue is formed only when the formation of embryo has taken place by fertilization of the oosphere or egg. Angiosperms are, therefore, economical and more specialized as compared to gymnosperms where a large nutritive female gametophyte is formed long before fertilization. If fertilization fails, the energy spent on forming it shall go waste.

3. Double fertilization provides the characteristics of the male plant as well to the nutritive tissue.

4. Due to its triploid nature, endosperm shows high physiological activity, grows faster and accumulates nutrients.

Differences between Fertilization and Double Fertilization

Fertilization	Double Fertilization
1. It is the union of two compatible gametes.	1. It is union of one male gamete with egg and the other male gamete with secondary nucleus of the same embryo sac.
2. It occurs in almost all eukaryotes.	2. It is restricted to angiosperms only.
3. Fertilization produces a diploid zygote.	3. Double fertilization produces a diploid zygote and a triploid primary endosperm cell.

Artificial Hybridisation

It is human performed crossing of two different plants having complementary good traits in order to obtain an overall superior variety. Artificial hybridisation has been used by plant breeders for crop improvement programme even before the days of Mendel. Two precautionary measures in artificial hybridisation are emasculation and bagging. **Emasculation** is removal of stamens from the floral buds of female parent so that chances of self pollination are eliminated. **Bagging** is the covering of flowers by butter paper or polythene. The emasculated floral buds of the female parents and the floral buds of the male parents are bagged in order to protect them from contamination. Pollen grains of the male parents are collected as their anthers mature. As the stigmas of the emasculated flowers of the female parents mature, the covering bags are removed one by one for dusting their stigmas with pollen grains of desired variety. After pollination, the flowers are **rebagged** till the fruits begin to ripen. The latter will contain seeds of hybrid variety. A number of crosses may be required for obtaining the desired variety.

Emasculation is not required if the flowers are unisexual. However, both the type of flowers must be kept covered by bags. This protects them from contamination by unwanted pollen grains.

Post-Fertilization Changes

Soon after pollination, the flower begins to fade. It is sometimes accompanied by sudden increase in respiration and ethylene production. The petals, stamens and style wither away. The calyx may persist (e.g., Tomato, Brinjal) and even show growth as in *Physalis* and *Dillenia*. Other changes which take place are endosperm formation, embryo development, seed formation and fruit formation.

Endosperm — Structure, Types and Development (Fig. 2.29)

Endosperm is the name of food laden tissue which is meant for nourishing the embryo in seed plants. In gymnosperms it represents the female gametophyte. In angiosperms the endosperm is a **special tissue** which is formed as a result of vegetative fertilization, triple fusion or fusion of a male gamete with diploid secondary nucleus of the central cell. The fusion product is **primary endosperm cell** having a triploid endosperm nucleus.

Depending upon the mode of its formation, angiospermic endosperm is of three types—nuclear, cellular and helobial.

1. **Nuclear Endosperm.** The primary endosperm nucleus divides repeatedly without wall formation to produce a large number of free nuclei. Meanwhile central vacuole appears in the central cell and pushes the cytoplasm containing the nuclei to the periphery. The cytoplasm thickens so that the vacuole decreases in size. It ultimately disappears with the exception of a few cases. The multinucleate cytoplasm undergoes cleavage and gives rise to a multicellular tissue, e.g., Maize, Wheat, Rice, Sunflower, *Capsella bursa-pastoris*. In several cases, the cell wall formation remains incomplete. For example, Coconut has multicellular endosperm (called coconut meal) in the outer part and free nuclear as well as vacuolate endosperm (called coconut milk) in the centre. **Coconut milk** is highly nutritious. It is considered as energy drink because it is rich in minerals, vitamins, sugars, proteins and is isotonic with our body fluids. In *Phaseolus* wall formation occurs around the embryo only while in *Crotalaria* it is restricted to the upper half.

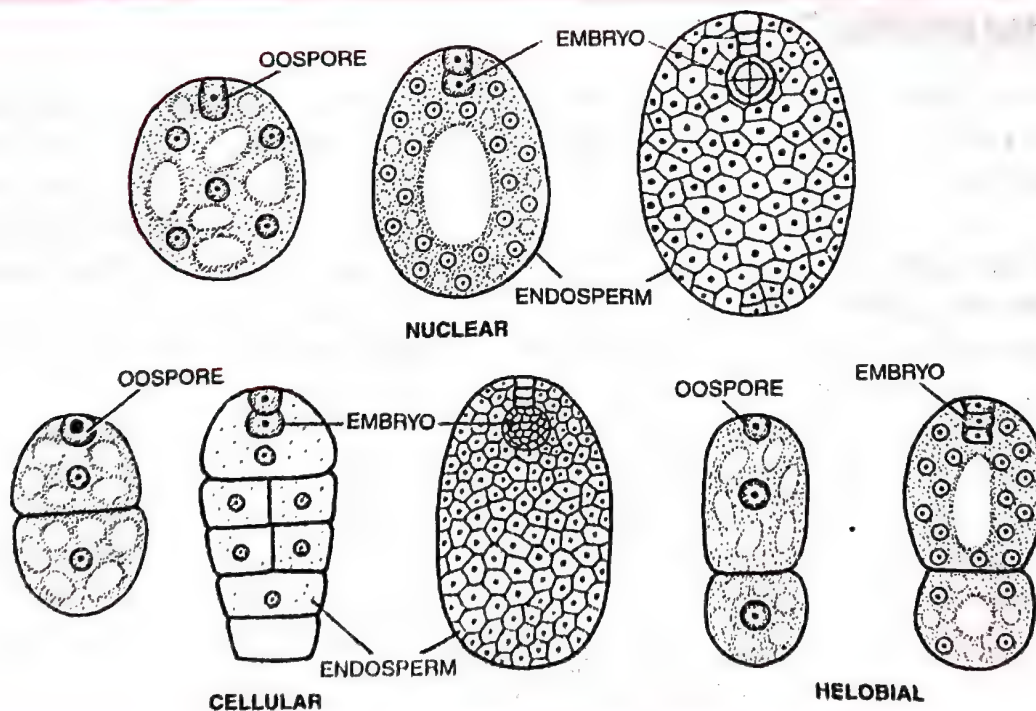


Fig. 2.29. Types of endosperm.

Nuclear endosperm is the most common type of endosperm. It is named so because it contains free nuclei in the beginning.

2. **Cellular Endosperm.** Every division of the primary endosperm nucleus is followed by cytokinesis. Therefore, endosperm becomes cellular from the very beginning, e.g., Balsam, *Datura*, *Petunia*.

3. **Helobial Endosperm.** It occurs in order helobiales of monocots. The endosperm is of intermediate type between cellular and nuclear types. The first division of primary

endosperm nucleus is followed by transverse cytokinesis to form two unequal cells, larger micropylar and smaller chalazal. Micropylar cell grows faster than the chalazal one. Further development in both the cells occurs like that of nuclear endosperm, *i.e.*, multinucleate stage followed by wall formation, *e.g.*, *Asphodelus*. However, chalazal chamber often remains smaller and may degenerate.

Fate of Endosperm. During its growth the endosperm crushes the nucellus. It is in turn eaten by growing embryo. The endosperm may persist in the seed when the latter is called endospermic or albuminous (*e.g.*, Castor, Cereals, Coconut). In others, the endosperm is completely absorbed by the growing embryo and the food reserve gets stored in the cotyledons. Such seeds are called nonendospermic or exalbuminous, *e.g.*, Pea, Bean, Sunflower.

Endosperm becomes convoluted in *Areca* (vern. Supari) and *Passiflora*, called ruminant endosperm. In *Areca*, Date (*Phoenix*) and Vegetable Ivory (*Phytelphas microcarpa*), the endosperm becomes very hard. The cellulosic hard endosperm of vegetable ivory is used to make buttons, umbrella handle heads and billiard balls.

Embryo — Structure, Types and Development

Embryogeny is the sum total of changes that occur during the development of a mature embryo from a zygote or oospore.

(a) **Embryogeny in Dicots.** In a typical dicot (Fig. 2.30) the zygote elongates and then divides by a transverse wall into two unequal cells (Schulz and Jensen, 1969). The larger basal cell is called **suspensor cell**. It has a large central vacuole. The smaller denser terminal or apical cell towards the antipodal end is termed **embryo cell**. The suspensor cell divides transversely a few times to produce a filamentous suspensor of 6–10 cells. The suspensor helps in pushing the embryo in the endosperm. The first cell of the suspensor towards the micropylar end becomes swollen and functions as a **haustorium**. The haustorium has wall ingrowths similar to transfer cells (Schulz and Jensen, 1969). The last cell of the suspensor at the end adjacent to the embryo is known as **hypophysis**. Hypophysis later gives rise to the radicle and root cap.

The embryo cell undergoes two vertical divisions (quadrant stage) and one transverse division to form eight cells arranged in two tiers (octant stage)— **epibasal** (terminal) and **hypobasal** (near the suspensor). The epibasal cells eventually form the two cotyledons and the plumule. The hypobasal cells produce the hypocotyl except its tip.

The eight embryonic cells or octants divide periclinally to produce an outer layer of **protoderm** or **dermatogen**. The inner cells differentiate further into **procambium** (= plerome) and **ground meristem** (= periblem). Protoderm forms epidermis, procambium gives rise to stele or vascular strand and ground meristem produces cortex and pith.

Initially the embryo is **globular** and undifferentiated. Early embryo with radial symmetry is called **proembryo**. It is transformed into embryo with the development of radicle, plumule and cotyledons. Two cotyledons differentiate from the sides with a faint plumule in the centre. At this time the embryo becomes **heart-shaped**. The rate of growth of the cotyledons is very high so that they elongate tremendously while the plumule remains as a small mound of undifferentiated tissue.

Structure of Dicot Embryo : A typical dicotyledonous embryo (Fig. 2.30 H) consists of an embryonal axis and two cotyledons. The part of embryonal axis above the level of cotyledons is called **epicotyl**. It terminates with the stem tip, called **plumule** (future shoot). The part below the level of cotyledons is called **hypocotyl** which terminates in the root tip called **radicle** (future root). The root tip is covered with a root cap (calyptra).

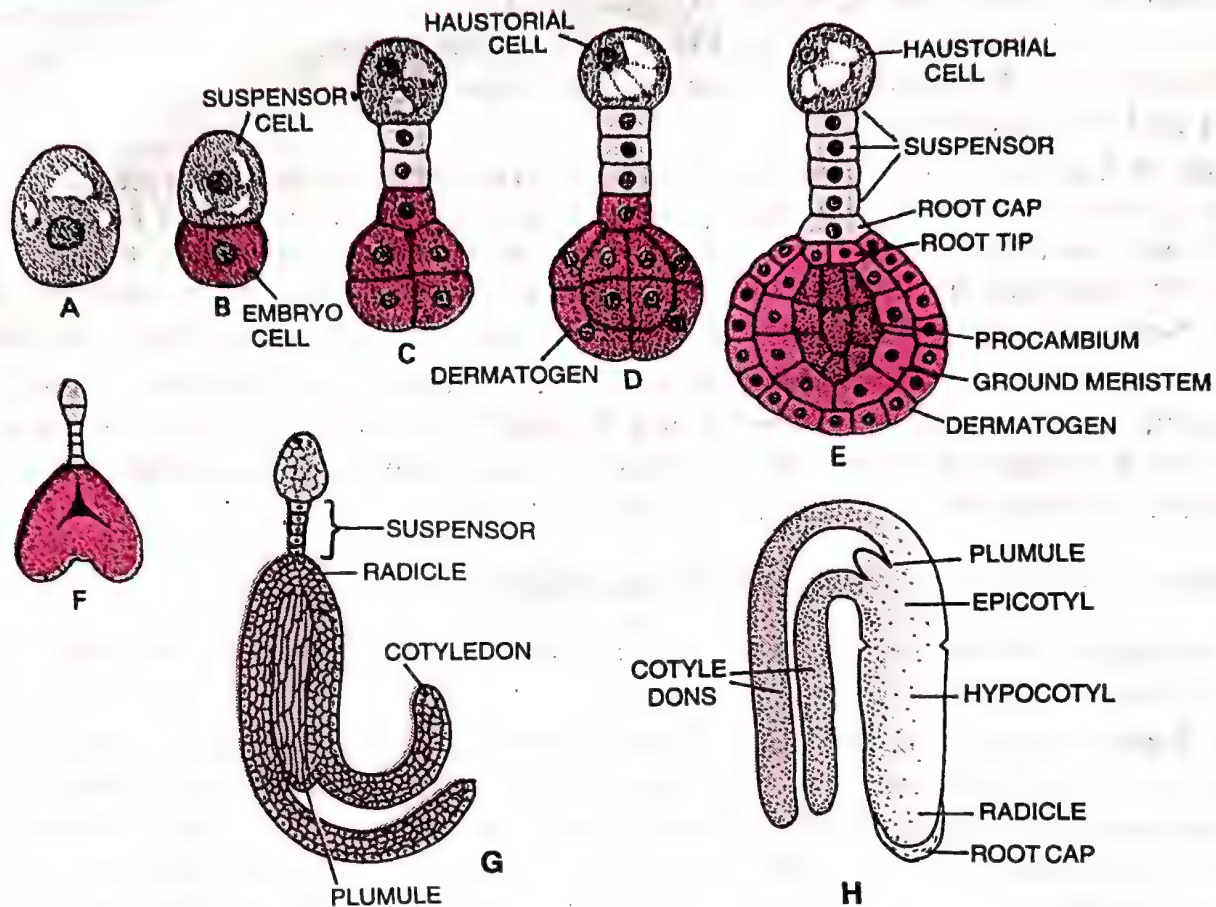


Fig. 2.30. Stages in the development of a dicot embryo. A, Zygote or oospore. B, Division of zygote into suspensor and embryo cells. C, Formation of suspensor and embryo octant. D, Periclinal divisions of embryo octants to form outer dermatogen. E, Globular embryo showing regions of radicle, procambium, ground meristem and dermatogen. F, Heart-shaped embryo. G, Mature dicotyledonous embryo. H, a typical dicot embryo.

In *Capsella bursa-pastoris*, the elongating cotyledons curve due to the curving of the ovule itself. With the growth of embryo, the ovule enlarges. Its integuments ultimately become hard to form protective coverings. Now the embryo undergoes rest and the ovule gets transformed into seed. In some plants the embryo remains in the globular or spherical form even at the time of seed shedding without showing any distinction of plumule, radicle and cotyledons, e.g., *Orobanch*e, *Orchids*, *Utricularia*.

(b) **Embryogeny in Monocots.** The zygote or oospore elongates and then divides transversely to form **basal** and **terminal** cells. The basal cell (towards micropylar end) produces a large swollen, vesicular **suspensor cell**. It may function as **haustorium**. The terminal cell divides by another transverse wall to form two cells. The top cell after a series of divisions forms plumule and a single cotyledon. Cotyledon called **scutellum**, grows rapidly and pushes the terminal plumule to one side. The plumule comes to lie in a depression. The middle cell, after many divisions forms hypocotyl and radicle. It also adds a few cells to the suspensor. In some cereals both plumule and radicle get covered by sheaths developed from scutellum called **coleoptile** and **coleorhiza** respectively.

Structure of Monocot Embryo. The embryos of monocotyledons (Fig. 2.31 H) have only one cotyledon. In grass family (Gramineae), this cotyledon is called **scutellum**. It is situated towards lateral side of embryonal axis. This axis at its lower end has radicle and root cap enclosed in a sheath called **coleorhiza**. The part of axis above the level of attachment

of scutellum is called **epicotyl**. It has as shoot apex and few leaf primordia enclosed in a hollow foliar structure called **coleoptile**. Epiblast represents rudiments of second cotyledon.

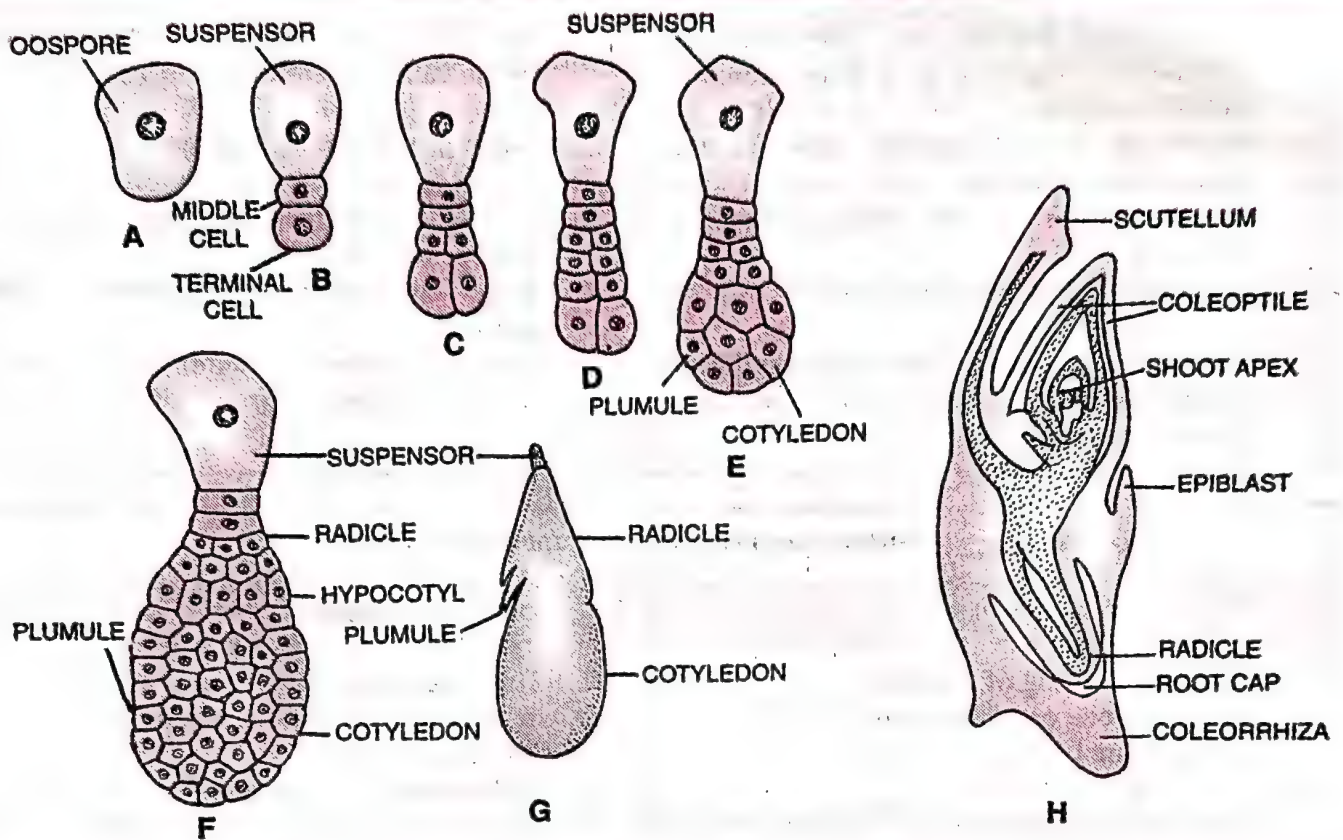


Fig. 2.31. A–G; Stages in development of a monocot embryo. H, a monocot embryo of a grass.

Differences between Dicot and Monocot Embryos

<i>Dicot Embryo</i>	<i>Monocot Embryo</i>
1. Basal cell forms a 6-10 celled suspensor.	1. Basal cell produces a single celled suspensor.
2. Terminal cell produces embryo except the radicle.	2. It forms the whole of the embryo.
3. The first division of terminal cell is generally longitudinal.	3. It is transverse.
4. It has two cotyledons.	4. There is a single cotyledon.
5. Plumule is terminal and lies in between the two elongated cotyledons	5. Plumule appears lateral due to excessive growth of the single cotyledon.

Differences between Epicotyl and Hypocotyl

<i>Epicotyl</i>	<i>Hypocotyl</i>
1. It is the part of embryonal axis in between plumule and cotyledonary node.	1. It is the part of embryonal axis in between cotyledonary node and radicle.
2. In hypogeal germination, epicotyl elongates so that cotyledons remain in the soil.	2. In epigeal germination, hypocotyl elongates so that cotyledons come out of soil.
3. The terminal end of epicotyl is plumule.	3. The terminal end of hypocotyl is radicle.

Differences between Coleoptile and Coleorhiza

<i>Coleoptile</i>	<i>Coleorhiza</i>
<ol style="list-style-type: none"> 1. The epicotyl bearing shoot apex and leaf primordia is enclosed in a foliar structure called coleoptile. 2. Coleoptile has a terminal pore for the emergence of first leaf. 3. It protects the plumule during emergence from soil. 4. It grows much beyond the grain. 5. Coleoptile after emergence from soil during germination, becomes green and does photosynthesis. 	<ol style="list-style-type: none"> 1. The radicle and root cap are enclosed in a sheath called coleorhiza. 2. Coleorhiza is a solid structure. 3. It does not protect the radicle during its passage into the soil. 4. After emergence from grain it stops growing. 5. Coleorhiza does not come out of soil. It remains nongreen.

Differences between Integument and Testa

<i>Integument</i>	<i>Testa</i>
<ol style="list-style-type: none"> 1. It is the covering of the ovule. 2. It is thin, one or two layered. 3. Its cells are living. 4. Sclereids are absent. 5. It arises from chalazal end of ovule. 6. It is a prefertilized structure. 	<ol style="list-style-type: none"> 1. It is outer covering of seed. 2. It is quite thick and one layered. 3. Its cells are dead. 4. Cells are rich in sclereids. 5. It is derived from outer integument of ovule after fertilization. 6. It is a post fertilized structure.

Differences between Perisperm and Pericarp

<i>Perisperm</i>	<i>Pericarp</i>
<ol style="list-style-type: none"> 1. It is unused nucellus in the seed. 2. It is a part of seed. 3. It is usually dry. 4. It is often nonfunctional for seed. 5. Perisperm is present in only a few seeds. 	<ol style="list-style-type: none"> 1. It is the covering of fruit that develops from ovary wall. 2. It is a part of fruit. 3. It is dry or fleshy. 4. It is protective covering and also helps in dispersal and nutrition. 5. It is found in all fruits.

Significance of Seed and Fruit Formation

Seed and fruit formation are stimulated by the act of fertilization. In angiosperms double fertilization produces two structures—a diploid zygote or oospore and a triploid primary endosperm cell. The latter gives rise to a nutritive tissue called endosperm. Zygote forms the embryo. Endosperm provides nourishment to the growing embryo. With the growth of embryo the central part of the endosperm is eaten up. Endosperm in turn corrodes over the nucellus. In some seeds, the endosperm persists in the seed as food storage tissue. Such seeds are called **endospermic** or **albuminous**, e.g., Castor, Maize, Wheat, Barley, rubber, coconut. In others the endosperm is completely eaten up by growing embryo. The food for later development of embryo is then stored in cotyledons which become massive. Such seeds

are **nonendospermic** or **exalbuminous**, e.g., Pea, Gram, Bean, Groundnut. In some seeds remains of nucellus persist. The residual nucellus which persists in the seed is called **perisperm**, e.g., Black pepper, Coffee, Castor, Cardamum, Nymphaea. As the embryo reaches maturity its further growth is suspended due to development of growth inhibitors, abscission of funiculus or changes in integuments. The cells of the integuments lose their protoplasm, develop thick and impermeable walls. The integuments thus get transformed into seed coats, outer **testa** and inner **tegmen**. The moisture content of seed decreases and reaches 10–15%. In this dry seed, the embryo occurs in state of inactivity called **dormancy**. The micropyle of the ovule is changed in micropyle of seed. Through this pore, oxygen and water enter the seed at the time of germination.

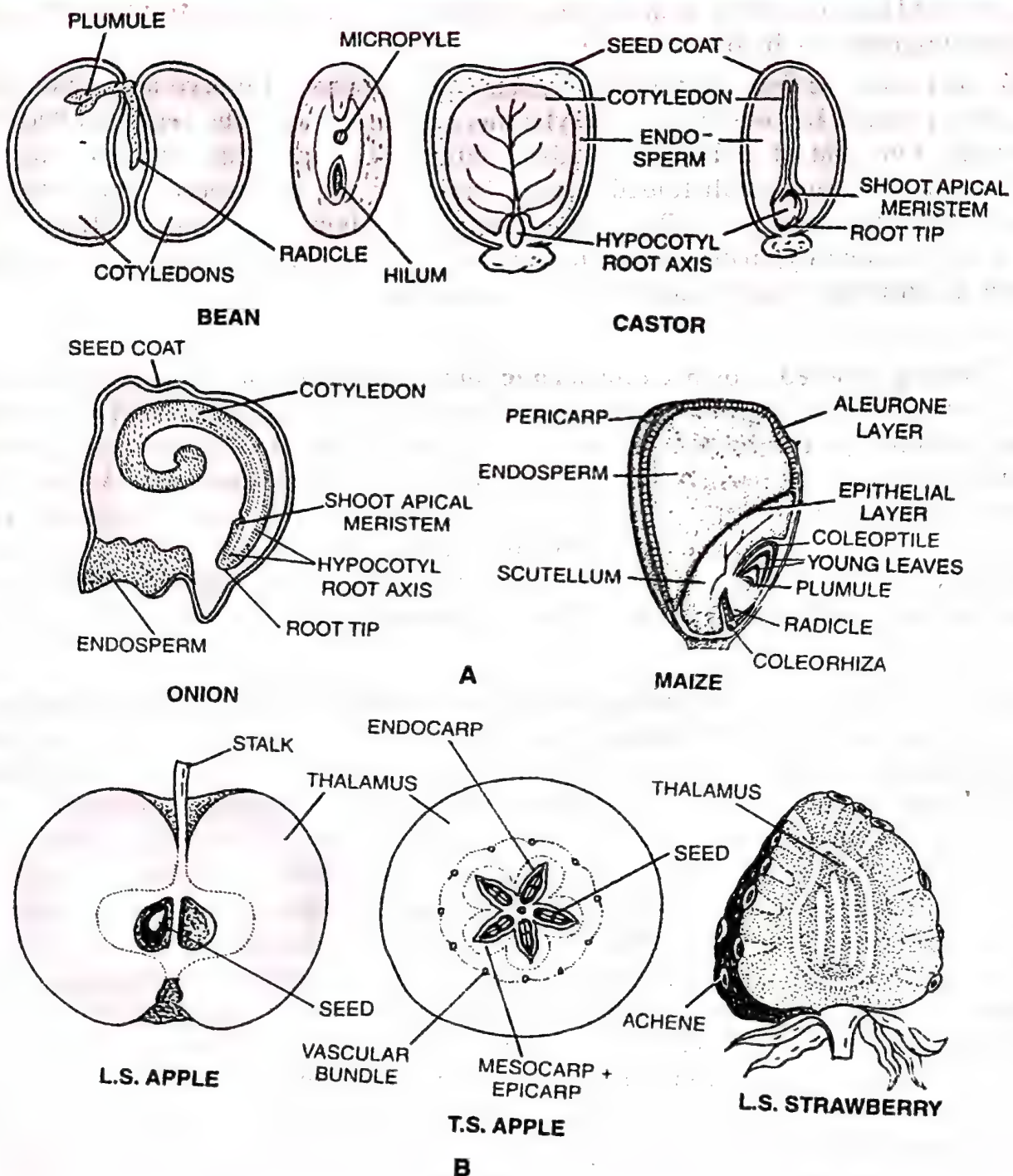


Fig. 2.32. A, Structures of some seeds. B, False fruits of Apple and Strawberry.

The tissue of the ovary wall is also stimulated to grow with the development of the seed. It produces a fruit wall or **pericarp**. In some cases, **thalamus** and other floral parts also show proliferation along with the development of the ovary wall. They are called **false fruits**, e.g., Apple, Strawberry, Cashew. The fruits in which no part of the flower develops along with ovary are called **true fruits**. Some fruits also develop without fertilization. They are seedless fruits and are called **parthenocarpic fruits**, e.g., Banana. Parthenocarpy or production of seedless fruits can be induced artificially by means of hormones.

1. Bean Seed

It is kidney-shaped brownish **non endospermic dicotyledonous seed**. The surface is smooth. Concave surface is darker. It has a whitish scar or **hilum**, a small pore or **micropyle** and a faint ridge or **raphe**. A bulge of underlying **radicle** is observed on the opposite side of **raphe**. The seed is covered by a thick, tough, brownish seed coat or **testa**. A thin papery transparent **tegmen** lies below the **testa**.

Seed coats enclose the embryo. There is no other structure. Embryo axis or **tigellum** is curved. It is covered by two massive **cotyledons** borne over it in the region called **cotyledonary node**. One end of embryo axis called **plumule** lies embedded in between the two cotyledons. It bears two small folded leaves. The other end of embryo axis is **radicle**. It protrudes out of the cotyledons. Part of the embryo axis lying between **radicle** and **cotyledonary node** is called **hypocotyl** while the part between the **cotyledonary node** and **plumule** is known as **epicotyl**. Food is stored in the cotyledons.

2. Castor Seed

It is oblong mottled brown **endospermic and dicotyledonous seed**. The narrow end bears a bilobed white spongy **caruncle**. Both **hilum** and **micropyle** occur in this area. **Raphe** develops from this part and proceeds towards the broad end where it bifurcates. A thick hard but brittle **testa** covers the seed. A thin **perisperm** lies below it and around the kernel. A white oily **endosperm** lies below the **perisperm**. It stores food reserve as oil drops and proteins. **Endosperm** is source of castor oil. **Embryo** lies in the centre of seed. It consists of a short embryo axis bearing two thin papery semitransparent oval cotyledons, a small indistinct **plumule** and a knob-shaped **radicle**. Palmate venation occurs over the cotyledons.

3. Maize Grain

It is a monocotyledonous, endospermic single seeded dry fruit called **caryopsis**. The grain is conical and flattened. Shallow husk occurs over the pointed end. On one side the broader end bears a **papilla** representing remains of the style. The same side has a depression in which a ridge indicates the position of underlying embryo. **Hilum** and **micropyle** are absent since grain is a fruit and the seed is internal. Colour is variable. Surface is nearly smooth. The covering of the grain is made of fused **pericarp** and **testa**. 2/3 of the grain interior has food storage tissue of **endosperm**. It is rich in starch. A protein rich **aleurone layer** lies on the outside of **endosperm**. Embryo lies on one side towards the upper pointed part. A single large cotyledon lies lateral and parallel to the embryo axis. It is called **scutellum**. **Scutellum** is attached to the middle part of embryo axis. Its outer layer in contact with **endosperm** is called **epithelial layer**. The layer secretes GA for formation of amylase from **aleurone** proteins during germination. Embryo axis ends in **plumule** towards broader side and **radicle** towards pointed side. **Radicle** has a root cap. **Plumule** bears a few small leaves. Sheaths derived from **scutellum** cover the two ends of embryo axis, undifferentiated **coleorhiza** over the **radicle** root cap region and hollow folial **coleoptile** over the **plumule**. Area of embryo axis is between **plumule** and **cotyledonary node** is **epicotyl** while the area between **cotyledonary node** and **radicle** is called **hypocotyl**.

4. Onion Seed

It is a small blackish endospermic monocotyledonous seed with wrinkled surface. Seed coat is quite tough. It is coloured. Endosperm or food storage tissue is also tough. It is semitransparent. Embryo is curved. It is embedded in the endosperm. Embryo axis is small as compared to single cotyledon called scutellum. Epicotyl is inconspicuous. Plumule is not distinguishable. Instead shoot apical meristem is present. A notch occurs in the area of origin of single cotyledon. Hypocotyl is larger. It bears radicle or root tip.

Viability of Seeds

The ability of seeds to retain the power of germination over a period of time is called viability of seeds. A viable seed is, therefore, that seed which is capable of germination under suitable environmental conditions (after the completion of dormancy, if it is present). Viability may range from a few weeks to several years. It is also influenced by conditions during storage and nongermination. Excessive dry or damp weather and high temperature are known to reduce viability of all seeds. Loss of viability is generally due to : (i) Exhaustion of food around the embryo. (ii) Damage to embryo. (iii) Denaturation of enzymes. (iv) Premature exhaustion of RNAs.

Viability of several hundred years has been recently found out. Some 2000 years old viable seeds of *Phoenix dactylifera* have been discovered during archaeological excavation of King Herod's palace near Dead sea. About 10000 years old seeds of *Lupinus arcticus* taken out from arctic tundra have germinated and produced plants that flowered and bore fruits.

Viability of seeds can be known by two methods : (i) Ability to germinate. (ii) Testing their ability to respire. All viable seeds respire. This can be tested by immersing a section of seed containing the embryo in 0.1% solution of **triphenyl tetrazolium chloride**. The viable embryo will turn pink due to conversion of colourless triphenyl tetrazolium chloride into insoluble coloured dye called **triphenyl formazan** due to reduction.

Importance of Seeds

1. **Dependable Method.** Unlike bryophytes and pteridophytes, pollination and fertilization of seed plants are free from requirement of water. Seed formation is, therefore, more dependable.

2. **Perennation.** Seed is dry (water content 10-15%) with dormant embryo and thick protective seed coat. It is most suitable for perennation through unfavourable periods.

3. **Dispersal.** Seeds have adaptive strategies to get dispersed to new habitats and colonise the same.

4. **Reserve Food.** Seeds have reserve food for nourishing the young seedlings till they become nutritionally independent.

5. **Variations.** As seeds are formed through sexual reproduction they carry a number of variations. Variations are essential for adaptability to diverse environmental conditions.

6. **Storage.** Seeds can be stored for later use. This is helpful for supply of food throughout the year and to overcome drought and famine conditions.

7. **Agriculture.** Seed is the basis of agriculture. Agriculture originated when humans learnt to eat, store and sow seeds. Agriculture proved to be turning point for evolution of human civilisation, industrialisation, science and technology.

Significance of Fruit Formation

1. **Protection.** Developing fruits protect the developing seeds from mechanical injury, insects and unfavourable climatic conditions.

2. **Dispersal.** Fruits help the seeds in dispersal to distant places.
3. **Food to Animals.** Fleshy fruits provide food to animals who also act as dispersal agents of their seeds. Fleshy fruits generally have hard seeds (e.g., Guava, Fig) while hard shelled fruits have soft seeds (e.g., Almond).
4. **Nutrition to Germinating Seeds.** Some fruits provide nutrition to germinating seeds and developing seedlings.
5. **Importance to Humans.** Fruits are a source of food, protein, oil, organic acids, vitamins, minerals and sugars.

Parthenocarp

(Gk. *parthenos*— virgin, *karpos*— fruit)

Production and development of seedless fruits is called parthenocarp. Mechanism of obtaining parthenocarpic fruits is becoming increasingly important because of three reasons : (i) Seeds are irritants during eating of the fruit. (ii) Processing of fruits by food industry requires the removal of seeds which is quite difficult. Therefore, seedless fruits are preferred by food industry. (iii) There is an increasing tendency to grow fruit bearing plants inside green houses. Reliable insect pollinators cannot be ensured in each and every case.

Parthenocarp is of two types, vegetative and stimulative (Westwood, 1993). In **vegetative parthenocarp** the seedless fruits can develop even without the stimulus of pollination, e.g., Pear, Fig. In **stimulative parthenocarp** the stimulus of pollination is required without the actual process of fertilisation or seed setting, e.g., Grapes. A number of fruit varieties (banana, Navel orange, pineapple, grapes) have been altered **genetically** to undergo parthenocarpic development. **Hormonal treatment** enables flowers to develop seedless fruits without the stimulus of pollination. The two commonly used hormones are auxins and gibberellins. Tomato produces seedless fruits if treated with auxin while grape-vine forms seedless fruits on being treated with gibberellin. Gibberellins are especially useful for inducing parthenocarp in pomes. Low temperature, frost and fog are found to induce parthenocarp in pear, olive, chillies and tomato.

Sexual Incompatibility

It is the inability of certain otherwise viable gametes to fuse with each other and produce fertile offspring. Sexual incompatibility may be interspecific or intraspecific. **Interspecific incompatibility** is important as it prevents free cross pollination or free cross fertilisation amongst members of different species. It maintains genetic individuality of the species. **Intraspecific incompatibility, self-sterility or self-incompatibility** is inability of a plant producing functional male and female gametes to produce fertile offspring when self pollinated. It is a mechanism to prevent inbreeding and promote **outbreeding**. Self incompatibility has been reported in 66 families of angiosperms (Mc Cubbin and Dickinson, 1997). It can be due to morphological or physiological reasons.

1. **Morphological Self Incompatibility.** There are two or three different mating types, e.g., distyly (*Primula*), tristyly (*Lythrum*).

2. **Physiological Self Incompatibility.** There is no morphological distinction amongst the different mating types found in the species. Physiological self incompatibility is of two types. (i) **Gametophytic Self Incompatibility (GSI).** The incompatibility is due to genotype of pollen, e.g., Liliaceae, Solanaceae, Poaceae. It prevents pollen germination, causes retardation of pollen growth, deorientation of pollen tubes and failure of nuclear fusion.

(ii) **Sporophytic Self Incompatibility (SSI)**. The incompatibility is due to genotype of sporophytic or stigmatic tissues, e.g., Asteraceae, Brassicaceae.

The genetic basis of self compatibility was proposed by East and Mangelsdorf (1925) in the form of multiallelic single gene, *S*-gene. It contains over 30 alleles in *Brassica oleracea*. Pollen grain contains a single allele while the stigma has two alleles. If the pollen grain allele (say S_1) is similar to any of the two alleles of the female parent (say $S_1 S_4$) incompatibility will ensue.

Importance

1. Self incompatibility prevents self pollination.
2. Self incompatibility has made the plants outbreeders. Outbreeding maintains vigour and vitality of the race.
3. Variations appear due to outbreeding provide adaptability to changes in environment.
4. Self incompatibility has a defect. It does not allow raising of pure lines required for breeding programmes.

Apomixis and Polyembryony

Apomixis (Gk. *apo*– without, *mixis*– mixing) is a mode of reproduction which does not involve formation of zygote through gametic fusion. It is, therefore, akin to asexual reproduction. In plants apomixis commonly mimics sexual reproduction but produces seeds without fertilisation, e.g., some species of Asteraceae and grasses. There are several methods of apomictic development in seeds. The two common ones are recurrent agamospermy and adventive embryony.

1. **Recurrent Agamospermy**. Agamospermy (Gk. *a*– without, *gamos*– marriage, *sperma*– seed) is the formation of seed that has an embryo formed without meiosis and syngamy. It is of two types, **noncurrent** and **recurrent**. In **noncurrent agamospermy**, the embryo is haploid. Therefore, the seed having it is nonviable. In **recurrent agamospermy** all the cells of embryo sac are diploid as it is formed directly either from a nucellar cell (**apospory**) or diploid megaspore mother cell (**diplospory**). The diploid egg as well as other diploid cells of embryo sac can grow into normal embryos. Formation of embryo directly from diploid egg without fertilization is called **diploid parthenogenesis**, e.g., *Rubus*, Apple, *Poa*.

2. **Adventive Embryony (Sporophytic Budding)**. An embryo develops directly from a diploid cell other than egg like that of nucellus and integument, e.g., *Citrus*, *Opuntia*. It gives rise to a condition called **polyembryony** or the phenomenon of having more than one embryo. There may be more than one egg cell in an embryo sac or more than one embryo sac in an ovule. All the egg cells may get fertilised. Synergids and antipodal cells may also form embryos. In gymnosperms polyembryony can also occur due to cleavage of growing embryo. It is called **cleavage polyembryony**. Occurrence of polyem-

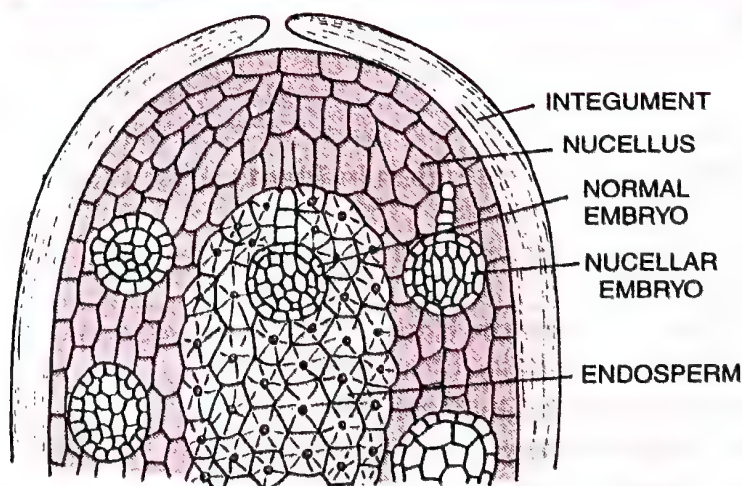


Fig. 2.33. *Citrus* ovule (Young seed) in section showing normal and nucellar (adventive) embryos.

bryony due to fertilisation of more than one egg is called **simple polyembryony**. Formation of extra embryos through sporophytic budding is called **adventive polyembryony**. Polyembryony is quite common in Onion, Groundnut, Mango, Lemon, Orange. In some of these cases stimulus of pollination may be required. In *Citrus* (Fig. 2.33) a seed has 2–40 embryos, one normal and the rest adventive, mostly nucellar. In *Allium odorum*, there are 5 embryos, all developed by different methods — one from zygote, one from synergid, 2 from antipodal cells and one from integument of ovule.

Differences between Parthenocarpy and Parthenogenesis	
<i>Parthenocarpy</i>	<i>Parthenogenesis</i>
<ol style="list-style-type: none"> 1. It is the production and development of seedless fruits without pollination and fertilization. 2. Parthenocarpic fruits are normal. 3. It occurs in plants only. 4. Examples : Banana, Pineapple, Guava, Grapes, Apple, Tomato, Papaya, etc. 	<ol style="list-style-type: none"> 1. It is the development of unfertilized egg into a complete individual without fertilization. 2. Young ones produced by parthenogenesis are generally weak. 3. It occurs in both plants and animals. 4. Examples : Plants such as <i>Solanum nigrum</i>, <i>Nicotiana</i>, <i>Datura</i>, <i>Oenothera</i> etc and animals like, Drones, <i>Lacerta saxicola armaniaca</i>, <i>Typhlina brahmina</i>, etc.

Importance

(i) Hybrid varieties provide higher and better yield. They are, therefore, preferred. A number of cereals and vegetables are being raised by using hybrid seeds. However, there is one major drawback. Hybrid seeds have to be produced every year because seeds collected from hybrid plants, if sown subsequently, do not maintain hybrid characters due to segregation of traits. Production of hybrid seeds every year is costly thus increasing the cost of crop production. This can be avoided if apomixis can be introduced in hybrid seeds. Apomixis is genetically controlled. Therefore, scientists are busy in identifying genes for apomixis so that they can be introduced in hybrid varieties.

(ii) Adventive embryos are better clones than cuttings.

(iii) Embryos formed through apomixis are generally free from infections.

ADDITIONAL INFORMATION

- **Sexual Reproduction in Plants.** First studied by Camerarius (1694).
- **Most Common Type of Ovule.** Anatropous (92%).
- **Most Common Embryo Sac.** *Polygonum*. First studied by Strasburger.
- **Anthology.** Study of flowers.
- **Largest Flower.** *Rafflesia* (1 m).
- **Smallest Flower.** *Wolffia*.
- **National Flower of India.** Lotus.
- **Allogamy.** Commonly used for cross pollination or xenogamy. Actually includes both geitonogamy and xenogamy.
- **Polyembryony.** Discovered by Leeuwenhoek (1719) in *Citrus*. Polyembryony is the phenomenon of developing more than one embryo in the same seed. It can develop due to (a) **Simple Polyembryony**. Presence of more than one embryo sac and hence oosphere, e.g., *Brassica*. (b) **Mixed Polyembryony**. More than one pollen tube entering an ovule and fertilizing synergid or an antipodal cell, e.g., *Ulmus*. (c) **Cleavage**

- Polyembryony.** Cleavage or splitting of one embryo into two or more embryos, e.g., Orchids, *Nymphaea*, *Nicotiana*. (d)
- Adventitive Polyembryony.** Diploid nucellar or integument cells proliferate to form embryos, e.g., *Citrus*, *Opuntia*, *Mangifera*. In *Balanophora*, an adventitive embryo can develop from endosperm. Polyembryony is called **true** if extra embryos develop from the same embryo sac and **false** if they are formed elsewhere.
- **Floriculture.** Science of cultivation, breeding, marketing and arrangement of flowers is called floriculture.
 - **Pomology.** The science and practice of fruit culture.
 - **Smallest Pollen.** *Myosotis* (2.5–3.5 mm).
 - **Largest Pollen.** *Mirabilis* (250 mm diameter) but the longest is that of *Zostera* (2500 mm).
 - **Xenia.** Effect of pollen on endosperm (Focke, 1881). Effect on other tissue is called **metaxenia**.
 - **Epizoochory.** Forced zoochory where animals carry the fruits and seeds over their body due to their attachment to feet, legs, fur, feathers, etc.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. Name the parts of an angiospermic flower in which development of male and female gametophyte takes place.
 - ✓ Development of male gametophyte (microgametogenesis) occurs in pollen sac of anther upto 2 celled stage. The female gametophyte develops (megagametogenesis) in the nucellus of ovule.
2. Differentiate between microsporogenesis and megasporogenesis. Which type of cell division occurs during these events ? Name the structures formed at the end of these two events.
 - ✓ **Differences.** Refer to text.
 - Microsporogenesis is the formation of haploid pollen grains from diploid MMCs. It occurs inside the pollen sac. Each MMC divides meiotically (**sporic meiosis**) to produce 4 pollen grains.
 - Megasporogenesis is the process of formation of haploid megaspores from diploid megaspore mother cell (MMC). It occurs inside the nucellus of ovule. The MMC divides meiotically (**sporic meiosis**) to produce 4 megaspores.
3. Arrange the following in correct developmental sequence:—

Pollen grain, sporogenous tissue, microspore tetrad, pollen mother cell, male gamete.

 - ✓ Sporogenous tissue, pollen mother cell, microspore tetrad, pollen grain, male gametes.
4. With a neat labelled diagram, describe the parts of a typical angiosperm ovule.
 - ✓ Refer to Fig. 2.13. Ovule is an integumented megasporangium that encloses an embryo sac. Common type of ovule is **anatropous**. **Parts.** 1. **Funicle.** Funicle is the stalk of the ovule. It is attached to placenta by funicle. In anatropous ovules the funicle is fused with the body of the ovule lengthwise to form **raphe**. Place of union of funicle and the body of ovule is called **hilum**.
 - 2. **Integuments.** They are one or two cuticularised coverings of the ovule. The place of origin of integuments is called **chalaza**. A pore occurs on one side of ovule where integuments are absent. It is known as **micropyle**.
 - 3. **Nucellus.** It is parenchymatous tissue contained in the ovule. Nucellus actually represents megasporangium.
 - 4. **Embryo Sac.** It is female gametophyte which is covered by a thin membrane. Embryo sac has seven cells. Three cells form **egg apparatus** towards micropylar end. There are two synergids and one egg or **oosphere** in the egg apparatus. Three cells on the opposite side are called **antipodal cells**. The seventh cell of the embryo sac is the largest cell. It is called **central cell**. Central cell has two polar nuclei which may fuse to form a diploid secondary nucleus.
5. What is monosporic development of female gametophyte ?
 - ✓ In 80% of angiosperms, out of 4 megaspores in a linear tetrad, only one remains functional and other three degenerate. The functional uninucleated megaspore divides by three mitosis to form an 8 nucleated, 7 celled embryo sac. This development of embryo sac from single uninucleated megaspore is called monosporic development.
6. What are chasmogamous flowers ? Can cross pollination occur in cleistogamous flowers ? Give reasons for your answer.

- ✓ Chasmogamous flowers are open flowers with exposed stamens and stigma. Cross pollination can not occur in cleistogamous flowers, as flowers remain closed and no transfer of pollens is possible from one flower to another.
7. Mention two strategies evolved by flowers to prevent self-pollination in flowers.
 ✓ As self pollination causes inbreeding depression (decrease in vigour and vitality of the race), plants avoid self pollination and develop devices to promote cross pollination. **Piclinism** (unisexuality of flowers), **dichogamy** (maturation of stamens and stigma at different times), self incompatibility, herkogamy are few such devices to prevent self pollination.
 8. What is self incompatibility? Why does self pollination not lead to seed formation in self incompatible species.
 ✓ **Self incompatibility** or **Self sterility** is a genetic mechanism to prevent self pollination despite occurrence of fully viable pollen grains and ovules. The genes for self incompatibility are called **S-genes**. If a similar S-allele is present in both the pollen grains (e.g., S_1) and stigma (e.g., S_1S_2), the pollen grain does not form functional pollen tube for carrying the male gametes to the ovule.
 9. What is bagging technique? How is it useful in plant breeding programme.
 ✓ It is the covering of emasculated flowers (removal of anthers in bud condition from a bisexual flower by a bag of butter paper or polythene in their bud condition (i.e., before anthesis) to prevent contamination of its stigma with unwanted pollens. When the stigmas of emasculated flowers mature the bags are removed, stigmas are dusted with pollen grains of desired male plants by means of a presterilized brush and flowers are rebagged till fruits develop.
 10. What is triple fusion? Where and how does it take place? Name the nuclei involved in triple fusion.
 ✓ Triple fusion is vegetative fertilization involving fusion of one male gamete with two haploid polar nuclei (or diploid secondary nucleus) to form triploid primary endosperm nucleus (PEN). It occurs in central cell of embryo sac. As it involves fusion of 3 nuclei (one male gamete and 2 polar nuclei). It is called triple fusion. Actually, first of all, two polar nuclei fuse to form a diploid secondary nucleus while then fuses with male gamete to form triploid PEN.
 11. Why do you think zygote is dormant for sometime in fertilized ovule?
 ✓ The development of zygote does not start prior to the development of PEN into endosperm. Endosperm provides nutrition to developing zygote into embryo and, therefore, zygote remains dormant for some time.
 12. Why is apple called false fruit? Which part of the flower forms the fruit?
 ✓ A false fruit (Pseudocarpic fruit) is that in which alongwith the ovary some other parts of the flower also grow and form a part of fruit. In apple, thalamus grows to form fleshy edible part of the fruit. **Ovary** forms the fruit after fertilization or without fertilization in parthenocarpic fruits.
 13. What is meant by emasculation? When and why does a plant breeder employ this technique. (NCERT)
 ✓ Emasculation is the technique of removing stamens in a floral bud before anthesis from a bisexual flower selected as female parent. It is done in a flower bud before anthesis when the sex organs are not exposed and anthers not dehiscent. The plant breeder employed this technique to prevent the pollination within same flower or to pollinate stigmas with pollens of desired variety.
 14. If one can induce parthenocarpy through application of growth substances, which fruits would you select to induce parthenocarpy and why?
 ✓ Parthenocarpic fruits are seedless. They develop from ovary without fertilization. Banana, grapes, oranges, Pineapple, Guava, Watermelon, lemon are selected because these seedless fruits are of high economic importance. The fruits in which seeds or seed part form edible portion (e.g., Pomegranate) are not selected to induce parthenocarpy.
 15. Explain the role of tapetum in pollen grain wall formation.
 ✓ The glandular tapetum produces Ubisch bodies coated with sporopollenin for increasing thickness of exine of pollen grains. Amoeboid tapetum contributes in the formation of exine.
 16. What is apomixis and what is its importance?
 ✓ Apomixis (Gr. *apo* = without; *mixis* = marriage) is a form of asexual reproduction that mimics sexual reproduction, in which seeds are produced without fertilization. It is common in grasses and species of Asteraceae family. It occurs by agamospermy, parthenogenesis and apogamy. All new individuals/embryos produced apomictically are genetically similar to the parent producing them and are **clones** of their parent.
 Apomicts have several advantages in horticulture and agriculture, particularly hybrid seed industry. The hybrid varieties are vigour more productive. The production of hybrid seeds is very costly, time

consuming and such seeds do not maintain hybrid vigour in progeny due to segregation of characters/genes during and meiosis. If the hybrids are made into apomicts, there will be no segregation of genes due to no meiosis, and the hybrid characters will pass on unchanged from one generation to other. It will reduce the cost on purchasing hybrid seeds by the farmer every year.

17. With a neat labelled diagram, explain the 7-celled, 8-nucleate mature female gametophyte.
✓ Refer to Fig. 2.15. For description see text.
18. Differentiate between (a) Hypocotyl and epicotyl (b) Coleoptile and coleorhiza (c) Integument and testa (d) Perisperm and pericarp.
✓ Refer to the text.

TEXT QUESTIONS

One Mark Questions (With Answers)

1. What is funiculus ?
✓ Stalk of ovule.
2. An embryo sac is formed directly from a nucellar cell. What is it called ?
✓ Apospory.
3. Define palynology ?
✓ Study of pollen grains.
4. What is the type of pollination when a snail pollinates the flower ?
✓ Malacophily
5. What types of structures are formed at the end of micro and mega sporogenesis ?
✓ Microsporogenesis produces four **haploid pollen grains**, arranged generally in a tetrahedral tetrad.
Megasporogenesis produces four **haploid megaspores** arranged in a linear tetrad.
6. Name the part of the flower which tassels of the corn cob represent. (CBSE 2014)
✓ Style (Tassel actually represents male inflorescence)
7. Give an example of a plant which came into India on a contaminant and is cause of pollen allergy. (CBSE 2014)
✓ *Parthenium hysterophorus* (Carrot Grass)

One Mark Questions (Without Answers)

1. Give the term of pollination by bats.
2. What is malacophily ?
3. Define parthenocarpy. Give one example in which it occurs naturally. (CBSE 2005 Comptt.)
4. Name the types of cross pollination found in Silk cotton Tree and *Vallisneria* respectively. (CBSE 2006 Comptt.)
5. Wind pollinated flowers are not visited by honey bees. Give two reasons.
6. Name any one bird-pollinated flower and mention one most important characteristic of such flowers.
7. What is parthenocarpy ?
8. Why are pollen grains produced in enormous quantity in maize ? (AISSSE 2001)
9. Define anemophily.
10. What do you mean by hydrophily ?
11. What is pomology ?
12. What is pericarp ?
13. What is the site of microsporogenesis ?
14. The meiocyte of Rice has 24 chromosomes. How many chromosomes are present in its endosperm? (CBSE 2009)
15. The microscopic pollen grain of the past are obtained as fossils. Mention the characteristics of pollen grains that makes it happen. (CBSE 2009)
16. Mention the pollinating agent of an inflorescence of small dull coloured flowers with well exposed stamens and large feathery stigma. Give any one characteristic of pollen grains produced by such flowers. (CBSE 2009)
17. Pea flowers produce assured seed sets. Give a reason. (CBSE 2010)

18. A bilobed, dithecous anther has 100 microspore mother cells per microsporangium. How many male gametophytes this anther can produce ? (CBSE 2010)
✓ $4 \times 100 \times 4 = 1600$
19. An anther with malfunctioning tapetum often fails to produce viable male gametophytes. Give one reason. (CBSE 2010)
20. Normally one embryo develops in one seed but when an orange seed is squeezed many embryos of different shapes and sizes are seen. Mention how it has happened. (CBSE 2011)
21. Why is banana considered a good example of parthenocarpy ? (CBSE 2012)
22. How do the pollen grains of *Vallisneria* protect themselves ? (CBSE 2012)

Two Mark Questions

1. Mention the reasons for difference in ploidy of zygote and primary endosperm nucleus in an angiosperm? (CBSE 2010)
2. How does floral pattern of Mediterranean orchid *Ophrys* guarantee cross pollination ? (CBSE 2010)
3. How many haploid cells are present in a mature female gametophyte of a flowering plant ? Name them (CBSE 2010)
4. Where does triple fusion take place in a flowering plant ? Why is it so called ? Mention its significance. (CBSE 2010)
5. Differentiate between albuminous and nonalbuminous seed, giving one example of each. (CBSE 2011)
6. State one advantage and one disadvantage of cleistogamy. (CBSE 2012)
7. Explain the function of (a) Coleorhiza (b) Germ pores. (CBSE 2012)
8. How does the study of different parts of a flower help in identifying wind as its pollinating agent ? (CBSE 2012)
9. In angiosperms, zygote is diploid while primary endosperm cell is triploid. Explain. (CBSE 2013)
10. Name all the haploid cells present in an unfertilised mature embryo sac of a flowering plant. Write the total number of cells in it. (CBSE 2013)
11. Differentiate between the two cells enclosed in a mature male gametophyte of an angiosperm. (CBSE 2013)
12. Name the organic materials the exine and intine of an angiosperm pollen grains are made of. Explain the role of exine. (CBSE 2014)
13. List the post fertilization events in angiosperms. (CBSE 2014)
14. Suggest two advantages to a farmer for using apomictic seeds of hybrid varieties. (CBSE 2015)
15. A single papaya plant in your kitchen garden produces pods with viable seeds, but the individual papaya plant does not. Explain. (CBSE 2016)
16. Gynoecium of a flower may be apocarpous or syncarpous. Explain with the help of an example each. (CBSE 2016)
17. Out of many papaya plants growing in your garden, only a few bear fruits. Give reason. (CBSE 2016)
18. A mature embryo sac in a flowering plant may possess 7-cells, but 8-nuclei. Explain with the help of a diagram only. (CBSE 2017)
19. Mention the ploidy of the different types of cells present in the female gametophyte of an angiosperm. (CBSE 2017)
20. A pollen grain in angiosperms at the time of dehiscence from an anther could be 2-celled or 3-celled. Explain. How are the cells placed within the pollen grain when shed at a 2-celled stage. (CBSE 2017)
21. "Pollen grains in wheat are shed at 3-celled stage while in pea they are shed at 2-celled stage." Explain. Where are germ pores present in a pollen grain. (CBSE 2017)
22. How many cells are present in the pollen grains at the time of their release from anther ? Name the cells. (CBSE 2017)

Three Mark Questions (Short Answer Type)

1. (i) Write the characteristic features of anther, pollen and stigma of wind pollinated flowers.
(ii) How do flowers reward their insect pollinators ? Explain. (CBSE 2010)
2. (a) Mention any four strategies adopted by flowering plants to prevent self-pollination.
(b) Why is geitonogamy also referred to as genetical autogamy ? (CBSE 2010)

3. Draw a longitudinal section of a post-pollinated pistil showing entry of pollen tube into a mature embryo sac. Label filiform apparatus, chalazal end, hilum, antipodals, male gametes and secondary nucleus. (CBSE 2010)
4. Draw a diagram of a male gametophyte of an angiosperm. Label any four parts. Why is sporopollenin considered the most resistant organic material? (CBSE 2011)
5. Differentiate between geitonogamy and xenogamy in plants. Which one between the two will lead to inbreeding depression and why? (CBSE 2011)
6. Differentiate between perisperm and endosperm giving one example of each. (CBSE 2012)
7. (a) Describe endosperm development in coconut.
(b) Why is tender coconut considered a healthy source of nutrition?
(c) How are Pea seeds different from Castor seeds with respect to endosperm? (CBSE 2013)
8. Explain any three advantages the seeds offer to angiosperms. (CBSE 2014)
9. Make a list of any three outbreeding devices that flowering plants have developed and explain how they help to encourage cross pollination. (CBSE 2014)
10. Why are angiosperm anthers called dithecal? Discuss the structure of its microsporangium. (CBSE 2014)
11. Why are some seeds referred to as apomictic seeds? Mention one advantage and one disadvantage to a farmer who uses them. (CBSE 2015)
12. Double fertilization is reported in plants of both Castor and Groundnut. However, the mature seeds of Groundnut are non-albuminous and Castor are albuminous. Explain the post-fertilization events that are responsible for it. (CBSE 2015)
13. Describe the development of endosperm after double fertilization in an angiosperm. Why does endosperm development precede that of zygote? (CBSE 2015)
14. (a) Name the organic material exine of the pollen grain is made up of. How is this material advantageous to pollen grain?
(b) Still it is observed that it does not form a continuous layer around the pollen grain. Give reason.
(c) How are pollen banks useful. (CBSE 2016)
15. (a) How does a farmer use the dormancy of seeds to his advantage.
(b) What advantages a seed provides to a plant? (CBSE 2016)
16. (a) How are parthenocarpic fruits produced by some plants and apomictic seeds by some others? Explain.
(b) When do farmers prefer using apomictic seeds? (CBSE 2016)
17. Parthenocarpy and apomixis have been observed in some plants. Give an example of each. State a similarity and a difference observed between the two. (CBSE 2017)
18. (a) Can a plant flowering in Mumbai be pollinated by pollen grains of the same species growing in New Delhi. Provide explanation to your answer.
(b) Draw the diagram of a pistil where pollination has successfully occurred. Label the parts involved in reaching the male gametes to its desired destination. (CBSE 2017)
19. Explain the process of pollination in *Vallisneria*. How is it different in water Lily, which is also an aquatic plant? (CBSE 2017)
20. (a) Trace the development of an endosperm after fertilization with reference to coconut. Mention the importance of endosperm development.
(b) Write the importance of "pollen bank". (CBSE 2017)

Five Mark Questions (Long Answer Type)

1. (a) Draw a diagrammatic sketch of a sectional view of a typical anatropous ovule. (CBSE 2014)
(b) List the components of the embryo sac and mention their fate on fertilization. (CBSE 2008)
2. (a) Draw a labelled diagram of a fertilized embryo sac of an angiosperm.
(b) Describe the stages in embryo development in a dicot plant. (CBSE 2008)
3. Explain with the help of a diagram, the development of a mature embryo sac from a megaspore mother cell in angiosperm. (CBSE 2009)
4. How does the pollen mother cell develop into a mature pollen grain? Illustrate the stages with labelled diagrams. (CBSE 2009)
5. (a) Draw a labelled diagram of a mature embryo sac. (CBSE 2014)
(b) Why does a pollen grain possess two male gametes? (CBSE 2009)

6. (a) Trace the development of embryo after syngamy in a dicot plant.
(b) Endosperm development precedes embryo development. Explain.
(c) Draw a diagram of a mature dicot embryo and label cotyledons, plumule, radicle and hypocotyl in it. (CBSE 2009)
7. (a) Draw a labelled diagram of L.S. of a flower to show the growth of pollen tube reaching egg apparatus.
(b) Pistil of a flower does not accept pollen from any plant other than from its own kind. How does it happen ? (CBSE 2009)
(c) What is syngamy ?
8. Describe in sequence the events that lead to the development of a 3 celled pollen grain from microspore mother cell in angiosperms. (CBSE 2010)
9. (a) Trace the development of megaspore mother cell upto the formation of a mature embryo sac in a flowering plant.
(b) Draw a labelled diagram of the structure of mature dicot embryo. (CBSE 2010)
10. (a) Draw a labelled longitudinal view of an albuminous seed.
(b) How are seeds advantageous to flowering plants ? (CBSE 2010)
11. Give reason why (i) Most zygotes in angiosperms divide only when certain amount of endosperm is formed. (ii) Groundnut seeds are exalbuminous and castor seeds are albuminous. (iii) Micropyle remains as a small pore in the seed coat of a seed. (iv) Integuments of an ovule harden and the water content is highly reduced as the seed matures. (v) Apple and Cashew are not called true fruits. (CBSE 2011)
12. (a) Draw a labelled diagram of L.S. of an embryo of grass (any six labels).
(b) Give reasons for each of the following : (i) Anthers of angiospermic flowers are described as dithecous. (ii) Hybrid seeds have to be produced year after year. (CBSE 2011)
13. (a) Why is fertilisation in an angiosperm referred to as double fertilization ? Mention the ploidy of the cells involved. (b) Draw a neat labelled sketch of L.S. of an endospermous monocot seed. (CBSE 2012)
14. (a) Draw a L.S. of a pistil showing pollen tube entering the embryo sac in an angiosperm and label any six parts other than stigma, style and ovary.
(b) Write the changes a fertilized ovule undergoes within the ovary in an angiospermic plant. (CBSE 2013)
15. (a) Why does endosperm development precede embryo development in angiosperm seeds? State the role of endosperm in mature albuminous seeds. (CBSE 2014)
(b) Describe with the help of three labelled diagram the different embryonic stages that include mature embryo of dicot plants. (CBSE 2014)
16. A flower of tomato plant following the process of sexual reproduction produces 240 viable seeds. Answer the following questions giving reasons :
(a) What is the minimum number of pollen grains that must have been involved in the pollination of this pistil ?
(b) What would have been the minimum number of ovules present in the ovary ?
(c) How many megaspore mother cells were involved ?
(d) How many male gametes were involved in this case ? (CBSE 2015)
17. (a) Explain the events after pollination leading to the formation of a seed in angiosperms.
(b) Mention the ploidy levels of the cells of different parts of an albuminous seed. (CBSE 2015)
18. (a) As a senior biology student, you have been asked to demonstrate to the students of secondary level in your school, the procedure (s) that shall ensure cross pollination in a hermaphrodite flower. List the different steps that you would suggest and provide reason for each one of them.
(b) Draw a diagram of a section of megasporangium of an angiosperm and label funiculus, micropyle, embryo sac and nucellus. (CBSE 2016)
19. (a) Explain the post pollination events leading to seed production in angiosperms.
(b) List the different types of pollination depending upon the source of pollen grain. (CBSE 2016)
20. (a) When a seed of an orange is squeezed, many embryos, instead of one are observed. Explain how it is possible ?
(b) Are these embryos genetically similar or different ? Comment. (CBSE 2017)
21. Read the following statement and answer the questions that follow : "A guava fruit has 200 viable seeds". (a) What are viable seeds ? (b) Write the total number of (i) Pollen grains (ii) Gametes in producing 200 viable guava seeds. (c) Prepare a flow-chart to depict the post-pollination events leading to viable-seed production in a flowering plant. (CBSE 2017)

Value Based Questions

- Amritya suffers from running nose, fever and bronchitis every year during late summer and autumn. What is the reason behind it. What should you suggest him and others with similar problem?
 ✓ Amritya is suffering from seasonal allergy which is usually caused by pollen grains of some plants being dispersed by air. In late summer and early autumn, the common weed responsible for allergic rhinitis is *Amaranthus spinosus* (Spiny Amaranth, Needle Burr). It is annual plant that grows in wild. Amritya must be living on the outskirts of the town where wild growth of plants is common. Even then he should undergo allergy test from an expert to find out the truth.
 - It is suggested that Amritya should shift to the interior of the town though it will have only small impact.
 - He should take anti-allergic medicine during the pollen season.
 - Amritya and other similar sufferers should undergo conditioning therapy to get cured from the allergy.
- Shreya was walking along with her young brother Srijan in the garden. Suddenly Srijan's attention was drawn towards a butterfly that was visiting one flower after another. He asked Shreya what was the butterfly doing. Shreya told her younger brother about honey collection and pollination by butterfly. What values were highlighted by Shreya?
 ✓ Butterfly visits the flowers for collecting honey which is its food. In the process it picks up pollen from anthers of one flower and deposits them over the stigma of another flower. The phenomenon is called cross pollination (entomophily).
 - It shows that both the plants and the butterflies are benefitted by their mutual cooperation — butterfly getting food and the plants getting pollinated.
 - Shreya gives instances of this cooperative behaviour in day to day working in the family. She helps her mother in many jobs while the mother takes care of her tiffin, clothes and other requirements.
 - Our society is based on cooperative working of its members, some are looking after electricity, water supply, communications, transport, education, health, removal of trash, supply of food stuffs, etc for payment made by every body.
- How are Rice and Wheat pollinated? Why is normal pollination absent in the two despite the flowers being chasmogamous?
 ✓ Rice and Wheat are two major cereals being consumed by humans throughout the world. Uniformity of their quality and their high yield are very important. Cross pollination can spoil the same. Their pollen grains are viable for only a few minutes. The period is sufficient for bud pollination to take place. Therefore despite being chasmogamous, Rice and Wheat are bud pollinated. The development/mutation must have been picked up by our ancestors to ensure good yield. Therefore, once a good high yielding variety has been raised by breeders, it can be maintained for a long time under field conditions.
 Changes as in Rice and Wheat have been selected by breeders in almost all crops. Potatoes are cultivated through tubers and not seeds. Sugarcane is grown through stem cuttings. Such developments are a legacy of our ancestors which must be further improved for the future generations.

Multiple Choice Questions (With Answers)

- Unisexuality of flowers prevents (a) autogamy and geitonogamy (b) both geitonogamy and xenogamy (c) autogamy but not geitonogamy (d) geitonogamy but not xenogamy. (CBSE 2008, NEET 2017)
- Endosperm is completely consumed by the developing embryo in (a) Pea and Groundnut (b) Maize and Castor (c) Castor and Groundnut (d) Maize and Pea. (CBSE 2008; AMU 2009)
- An advantage of cleistogamy is (a) it leads to greater genetic diversity (b) seed dispersal is more efficient and widespread (c) each visit of pollinator brings hundreds of pollen grains (d) seed set is not dependent on pollinators. (DPMT 2009)
- Transfer of pollen grains from the anther to the stigma of another flower of the same plant is called (a) Geitonogamy (b) Karyogamy (c) Autogamy (d) Xenogamy.
- Wind pollinated flowers are (a) Small, producing large number of dry pollens (b) Large, producing abundant nectar and pollen (c) small producing nectar and dry pollen (d) Small, brightly coloured, producing large number of pollen grains. (CBSE 2010)
- Wind pollination is common in (a) Grasses (b) Orchids (c) Legumes (d) Lilies. (CBSE 2011)
- In angiosperms, functional megaspore develops into (a) Endosperm (b) Pollen sac (c) Embryo sac (d) Ovule. (CBSE Mains 2011)

- (8) An organic substance which can withstand environmental extremes and which cannot be degraded by any enzyme is (a) Sporopollenin (b) Lignin (c) Cuticle (d) Cellulose. (CBSE 2012)
- (9) The function of germ pore is (a) Release of male gametes (b) Initiation of pollen tube (c) Absorption of water for seed germination (d) Emergence of radicle. (CBSE Mains 2012)
- (10) Megasprangium is equivalent to (a) Embryo (b) Nucellus (c) Ovule (d) Fruit. (NEET 2013)
- (11) Which is correct (a) Tapetum nourishes the developing pollen (b) Hard outer layer of pollen is called intine (c) sporogenous tissue is haploid (d) Endothecium produces the microspores. (NEET 2013)
- (12) Which part of flowering plant contains sporogenous tissue (a) stamen (b) pollen (c) microspores (d) young anthers. (JKCET 2014)
- (13) Pollen tablets available in market are for (a) Breeding programme (b) Supplementary food (c) *Ex situ* conservation (d) *In vitro* fertilization. (CBSE 2014)
- (14) Wheat/monocotyledonous seed has one large shield shaped cotyledon known as (a) Coleoptile (b) Scutellum (c) Aleurone layer (d) Coleorhiza. (JKCET 2015, CBSE 2015)
- (15) Male gametophyte of an angiosperm produces (a) two sperms and a vegetative cell (b) single sperm and a vegetative cell (c) single sperm and two vegetative cells (d) three sperms. (CBSE 2015)
- (16) The coconut water from tender coconut represents (a) free nuclear endosperm (b) endocarp (c) fleshy mesocarp (d) free nuclear proembryo. (NEET-I 2016)
- (17) Pollination in water hyacinth and water lily is brought about by the agency of (a) bats (b) water (c) insects or wind (d) birds. (NEET-II 2016)
- (18) Flowers which have single ovule in the ovary and are packed into inflorescence are usually pollinated by (a) water (b) bee (c) wind (d) bat. (NEET 2017)
- (19) Functional megaspore of an angiosperm develops into (a) ovule (b) endosperm (c) embryo sac (d) embryo. (NEET 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—

- (a) If both A and R are true and R is the correct explanation of A
(b) If both A and R are true and R is not the correct explanation of A
(c) If A is true but R is false
(d) If both A and R are false.

- Assertion.** Insects visit flowers to gather honey.
Reason. Attraction to flowers prevents the insects from damaging other parts of the plant.
(A) (B) (C) (D) (AIIMS 2004)
- Assertion.** In some species of asteraceae and poaceae, seeds are formed without fertilisation.
Reason. Formation of fruit without fertilization is called parthenocarp.
(A) (B) (C) (D) (AIIMS 2011)
- Assertion.** Endothecium layer of anther wall plays an important role in dehiscence of anther.
Reason. The presence of fibrous bands and differential expansion of inner and outer tangential walls of endothelial cells cause dehiscence of anther.
(A) (B) (C) (D) (NEET 2017)

ANSWERS

Multiple Choice Questions

- (1) —c (2) —a (3) —d (4) —a (5) —a (6) —a (7) —c (8) —a (9) —b (10) —b
(11) —a (12) —d (13) —b (14) —b (15) —a (16) —a (17) —c (18) —c (19) —c

Assertion and Reason Type Questions

- (1) —C (2) —B (3) —A

3

HUMAN REPRODUCTION

Sexual Dimorphism in Human Beings. When male and female individuals are differentiated externally, the phenomenon is called **sexual dimorphism**. Human beings show sexual dimorphism. The characters which distinguish the males and females externally are known as **secondary sex characters**.

Secondary Sex Characters in man and woman

Character	Man	Woman
1. General build up	More muscular	Less muscular
2. Aggressiveness	More marked	Less marked
3. Hair growth (i) Facial	Beard, moustache present	Absent
(ii) Axillary	Present	Present
(iii) Pubic	Hair distribution more lateral and upwards towards umbilicus.	Upward growth not so marked and is more, horizontal.
(iv) Chest	Present	Absent
4. Mammary glands	Undeveloped	Well developed
5. Skin	More hairy and coarse	Less hairy and coarse
6. Shoulder	Broad	Not broad
7. Pelvis	Not broad	More broad
8. Larynx	More apparent	Less apparent
9. Voice	Low pitched	High pitched
10. Breathing	Predominantly abdominal	Predominantly thoracic
11. BMR*	High due to greater activity	Not so high as compared to men.

Developmental Periods

They include embryonic or prenatal and post embryonic or postnatal (*natal* concerning birth).

1. **Embryonic Period (Prenatal Period).** In human beings this period is passed in mother's womb (uterus). It includes the events from the formation of an embryo to the time of birth.

2. **Post embryonic Period (Postnatal Period).** This period is passed outside the mother's womb. It includes the events from birth to the death of the individual.

Major Reproductive Events

The major reproductive events in human beings are as follows :

1. **Gametogenesis.** It is the formation of gametes. It includes **spermatogenesis** (formation of sperms) and **oogenesis** (formation of ova/eggs).

2. **Insemination.** It is the transfer of sperms by the male into the genital tract of the female.

3. **Fertilization.** Fusion of male and female gametes to form zygote is called fertilization.

*Basal Metabolic Rate is the amount of heat produced in the body in a given time in complete state of physical and mental rest at 20°C room temperature.

4. **Cleavage.** It is rapid mitotic divisions of the zygote which convert the single celled zygote into a multicellular structure called blastocyst (blastula).
5. **Implantation.** It is the attachment of blastocyst to the uterine wall.
6. **Placentation.** It involves the formation of placenta which is the intimate connection between the foetus and uterine wall of the mother to exchange the materials.
7. **Gastrulation.** It is the process by which blastocyst is changed into gastrula with three primary germ layers.
8. **Organogenesis.** It is the formation of specific tissues, organs and organ-systems from three primary germ layers.
9. **Parturition (Child Birth).** It involves expelling of the baby from the mother's womb (uterus).

HUMAN MALE REPRODUCTIVE SYSTEM

It consists of the following parts:

1. **Scrotum.** It is a pouch of deeply pigmented skin divided into two separate sacs. Each sac contains one testis. The normal temperature of the testes in the scrotum is about 2° – 2.5°C lower than the internal body temperature. This temperature is the ideal temperature for developing sperms. When the body is chilled, the smooth muscle contracts and brings the testes closer to the pelvic cavity. When the temperature drops, movement towards the pelvic cavity allows the testes to absorb heat from the rest of the body so that the sperm cells do not become chilled. The scrotum remains connected with the abdomen or pelvic cavity by the **inguinal canals**. The **spermatic cord**, formed from the spermatic artery, vein and nerve bound together with connective tissue passes into the testis through inguinal canal.

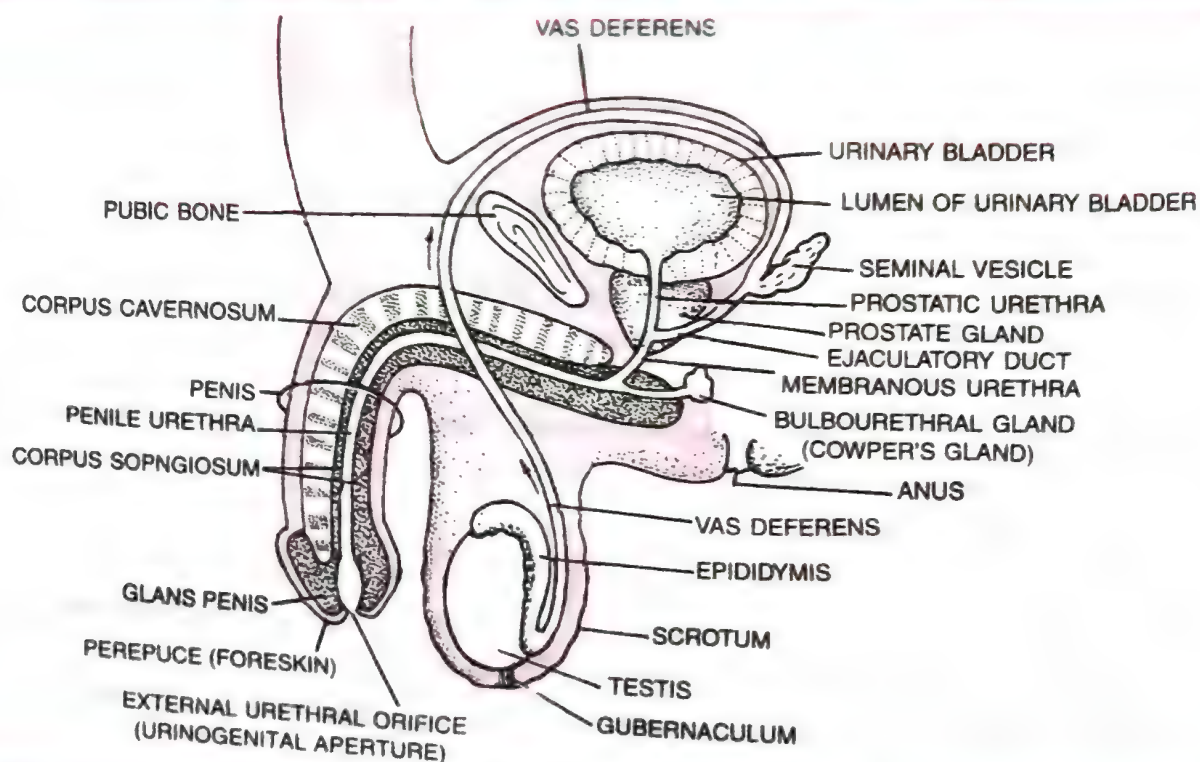


Fig. 3.1. Male Reproductive System in side view.

2. **Testes.** Testes are primary sex organs in man. During early foetal life the testes develop in the abdominal cavity but during the 7th month of the development they descend

into the scrotum through inguinal canals. There is a pair of testes that are suspended in the scrotum by the spermatic cords. A fibrous cord that extends from the caudal end of the testis to the scrotal wall is called **gubernaculum**. Each testis is oval in shape with a length of about 4 to 5 cm and a width of about 2 to 3 cm. The peritoneum, called **mesorchium** supports the testis.

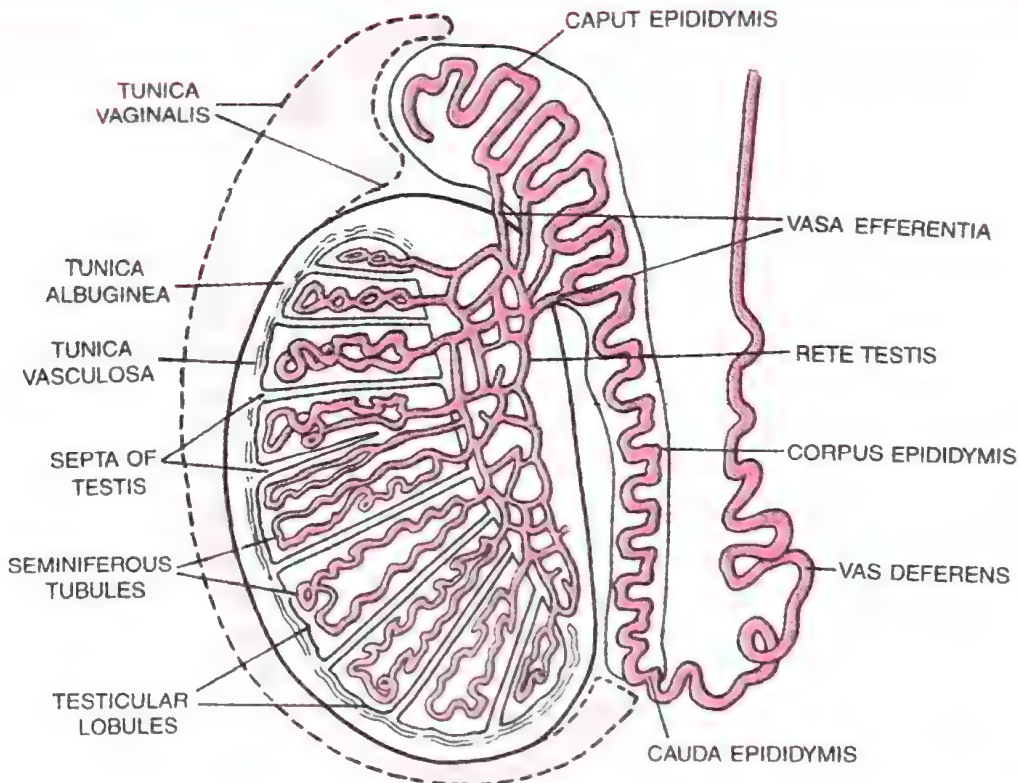


Fig. 3.2. Median longitudinal section of mammalian testis.

(i) **Protective Coverings (Tunicae).** The testis is surrounded by three layers. (a) The **tunica vaginalis** is the outer covering of the testis. (b) The **tunica albuginea** is a fibrous covering surrounding the testis situated under the tunica vaginalis. (c) The **tunica vasculosa** consists of a network of capillaries supported by delicate connective tissue which lines the tunica albuginea.

(ii) **Testicular Lobules.** Each testis has about 250 compartments called **testicular lobules**.

(iii) **Seminiferous Tubules** (Fig. 3.3 & 3.4).

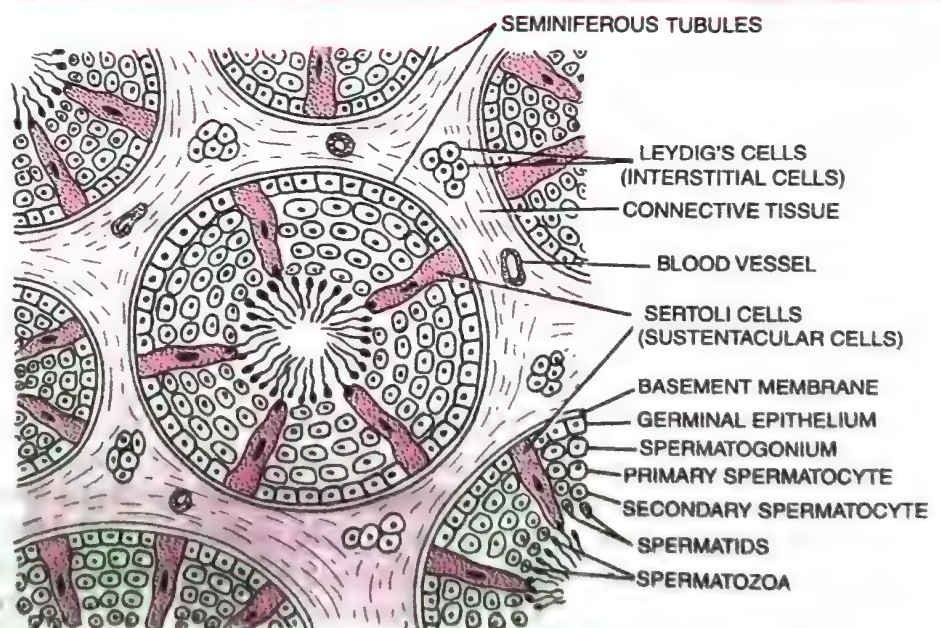


Fig. 3.3. A part of transverse section of mammalian testis showing seminiferous tubules.

Each testicular lobule of testis contains one to three highly coiled seminiferous tubules. Wall of each seminiferous tubule is formed of a single layered **germinal epithelium**. Majority of cells in this epithelium are cuboidal called **male germ cells** (spermatogonia) and at certain places, there are present tall **Sertoli or sustentacular cells**. These cells support developing germ cells and provide them with nutrition especially spermatids. Sertoli cells secrete **androgen binding protein** (ABP) that concentrates testosterone in the seminiferous tubules. Sertoli cells also secrete another protein called **inhibin** which suppresses FSH synthesis. The cuboidal cells undergo mitosis to produce **spermatogonia**. Spermatogonia grow into **primary spermatocytes** which undergo meiosis, producing haploid cells, first **secondary spermatocytes** and then **spermatids**. The latter convert into **spermatozoa** (sperms). Sertoli cells provide nutrition to the developing sperms.

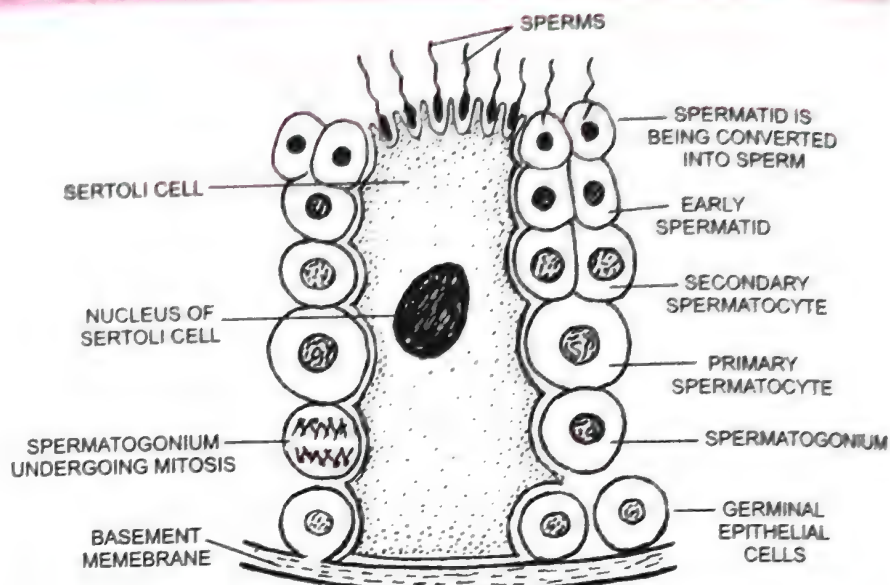


Fig. 3.4. Transverse section of a part of seminiferous tubule showing Sertoli cell and stages of spermatogenesis.

(iv) **Interstitial Cells or Leydig's Cells (Endocrine portion of the testis)**. In between the seminiferous tubules in the connective tissue, there are present small groups of rounded **interstitial** or **Leydig's cells** which secrete **androgens** (e.g., **testosterone**), i.e., male sex hormones.

(v) **Rete testis and vasa efferentia**. The seminiferous tubules are closed at one end but on the other side they join to a network the **rete testis** from where fine ciliated ductules, the **vasa efferentia** arise.

Thus testes perform two functions— production of sperms and secretion of male sex hormones.

Differences between Leydig's Cells and Sertoli Cells

Leydig's Cells (Interstitial Cells)	Sertoli Cells (Sustentacular Cells)
<ol style="list-style-type: none"> 1. They are present in between the seminiferous tubules. 2. Leydig's cells are found in small groups and are rounded in shape. 3. They secrete androgens (e.g., testosterone) — male sex hormones. 	<ol style="list-style-type: none"> 1. They are present in between the germinal epithelial cells of the seminiferous tubules. 2. Sertoli cells are found singly and are elongated. 3. They provide nourishment to the developing spermatozoa (sperms). Sertoli cells secrete ABP (Androgen Binding Protein) that concentrates testosterone in the seminiferous tubules. It also secretes another protein inhibin which suppresses FSH synthesis.

3. **Epididymes.** The epididymis is a mass of long narrow closely coiled tubule which lies along the inner side of each testis. At the anterior end of the testis it is called **caput epididymis**, in which the vasa efferentia open. The middle part of the epididymis is known as **corpus epididymis**. The posterior end of the epididymis is called as **cauda epididymis**. The epididymis stores the sperms and also secretes a fluid which is considered to nourish the sperms.

4. **Vasa deferentia.** A vas deferens emerges from the cauda epididymis on each side and leaves the scrotal sac and enters the abdominal cavity through the inguinal canal. The vas deferens loops over the urinary bladder where it is joined by duct from the **seminal vesicle** to form the **ejaculatory duct**. Vasa deferentia carry sperms.

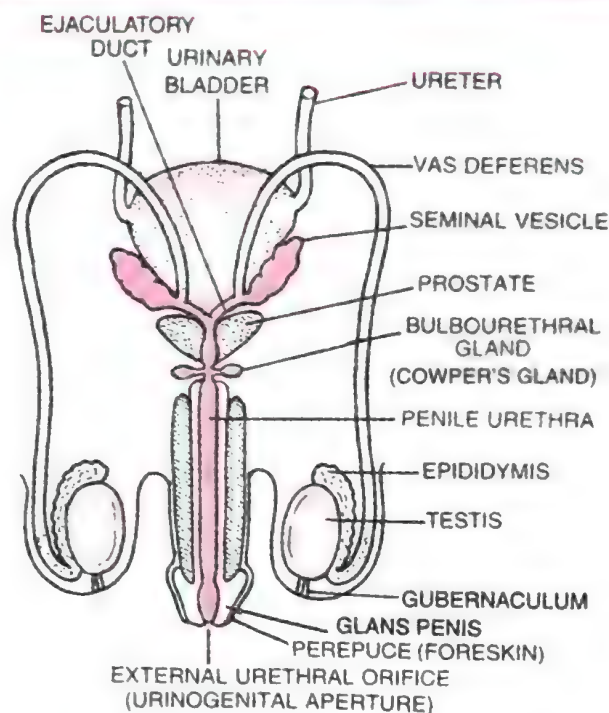


Fig. 3.5. Male reproductive system in front view.

Differences between Vasa efferentia and Vasa deferentia

<i>Vasa Efferentia</i>	<i>Vasa Deferentia</i>
<ol style="list-style-type: none"> 1. They arise from the rete testis. 2. They vary from 15 to 20 in number. 3. Vasa efferentia are fine. 4. Their lining bears many ciliated cells. 5. It carries spermatozoa from the rete testis to the epididymis. 	<ol style="list-style-type: none"> 1. They arise from the cauda epididymes. 2. They are only 2 in number. 3. Vasa deferentia are thick. 4. Their lining has many stereocilia. 5. It carries spermatozoa from cauda epididymis to the ejaculatory duct.

Rete testis, vasa efferentia, epididymes and vasa deferentia are called the **male sex accessory ducts**. These ducts store and transport the sperms from the testis to the outside through urethra.

5. **Ejaculatory ducts.** The ejaculatory ducts are two short tubes each formed by the union of the duct from a seminal vesicle and a vas deferens. They pass through the prostate gland and join the prostatic part of the urethra. The ejaculatory ducts are composed of the fibrous, muscular and columnar epithelial tissue. Ejaculatory ducts carry sperms and secretion of seminal vesicles.

6. **Urethra.** The male urethra provides a common pathway for the flow of urine called **semen**. It is much longer in male than in the female, measuring about 20 cm. The urethra includes three parts (i) The first part is surrounded by the prostate gland and is called the **prostatic urethra** which arises from the urinary bladder and carries urine only. (ii) The second part is the **membranous urethra** which is situated behind the lower part of the pubic symphysis. The membranous urethra is the smallest urethra. (iii) The third part is the **penile urethra** which is situated in the penis. There are two urethral sphincters. The **internal sphincter** consists of smooth muscle fibres situated at the neck of the bladder above the

prostate gland. The **external sphincter** consists of striated muscle fibres surrounding the membranous part of the urethra. Membranous urethra and penile urethra carry both urine and semen. External opening of the urethra is called **urethral meatus**.

Differences between Male and Female Urethra

Male Urethra	Female Urethra
1. It is much longer (about 20 cm in length).	1. It is short (about 4 cm in length).
2. It has three regions : prostatic (3-4 cm), membranous (1 cm) and penial (15 cm).	2. It is not differentiated into regions.
3. It opens out at the tip of the penis by urinogenital aperture.	3. It opens by urinary aperture in front of vaginal aperture.
4. It carries both urine and semen.	4. It carries only urine.

7. **Penis.** The penis is male genitalia (male copulatory organ). At the tip of the glans penis is the slit like opening called the **external urethral orifice** or **urinogenital aperture**. The penis in addition to conducting urine from the body, transfers semen into reproductive tract of the female during sexual intercourse. The penis contains three cylindrical masses of erectile tissue—two dorsal **corpora cavernosa** and one ventral **corpus spongiosum**. These bodies are surrounded by fibrous tissue. The corpus spongiosum which contains the penile urethra, is enlarged end of the penis to form the **glans penis**. The glans penis is covered by loose fold of skin, the **prepuce** or **foreskin**. During sexual arousal the three bundles of tissue in the penis become engorged with blood. The penis carries both urine and semen.

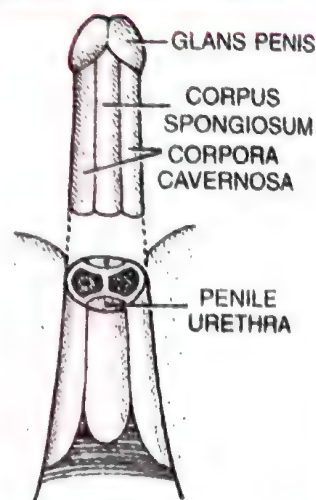


Fig. 3.6. Ventral view of penis.

8. Male Accessory glands.

(i) The **seminal vesicles** are one pair of sac like structures near the base of the bladder. Their ducts join the vasa deferentia to form the ejaculatory ducts. They produce an alkaline secretion which forms 60% of the volume of semen. The pH of seminal fluid is 7.4. The secretion of the seminal vesicles contains fructose, hormone – like **prostaglandins**, and clotting proteins that are different from those in blood. The fructose is a source of energy for the sperm. The prostaglandins stimulate uterine contractions and thus may help the sperm to be moved towards the female's oviducts, where fertilization takes place. The clotting proteins help semen coagulate after ejaculation. Alkaline nature of the seminal fluid helps to neutralize the acidic environment of the male urethra as well as that of female reproductive tract which otherwise would inactivate and kill sperms.

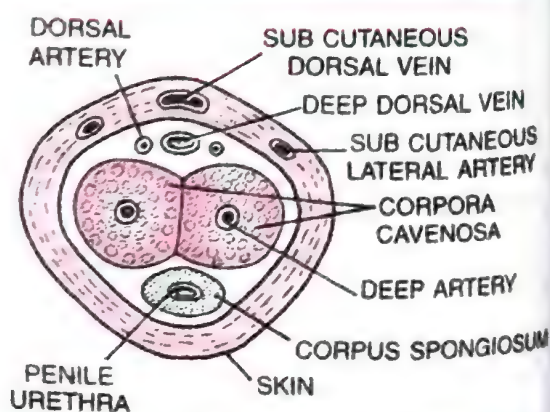


Fig. 3.7. T.S. of penis.

Fructose, which is produced by the seminal vesicles, is not present anywhere else in the body, provides a **forensic* test for rape**. The presence of fructose, in the female's genital tract confirms sexual intercourse.

*Pertaining to legal proceedings.

(ii) The **prostate gland** is a single large gland that surrounds the urethra. It produces a milky secretion with pH 6.5 which forms 25% of the volume of semen. This secretion contains citric acid (a sperm nutrient) and enzymes (acid phosphatase, amylase, pepsinogen) and prostaglandins. Due to the presence of citric acid it is slightly acid. A number of small ducts carry fluid from the prostate to the urethra. Secretion of the prostate gland nourishes and activates the spermatozoa to swim.

(iii) A pair of **bulbourethral glands** or **Cowper's glands** are present on either side of membranous urethra. These glands secrete an alkaline fluid. Their ducts open into the membranous urethra carrying the fluid that neutralizes acids from urine in the urethra. They also secrete mucus that lubricates the end of the penis and lining of the urethra. This decreases the number of sperms damaged during ejaculation.

Secretions of these glands constitute the **seminal plasma** which is rich in fructose, calcium and certain enzymes as mentioned above. The secretion of bulbourethral glands also helps in lubrication of the penis.

Secretion of bulbourethral glands carries some spermatozoa (sperms) released before ejaculation. This is one of the reasons for the high failure rate of the withdrawal method of birth control.

Primary and Secondary Sex Organs in Man

Testes are male gonads and produce male gametes (sperms) and male sex hormones. **Ovaries** are female gonads and produce female gametes (ova) and female sex hormones. The gonads are called the **primary sex organs**. The organs which neither produce gametes nor secrete sex hormones but perform important functions in reproduction are termed the **secondary sex organs**. The latter include the prostate, seminal vesicles, vasa deferentia and penis in male, and the fallopian tubes, uterus, vagina and mammary glands in females. The characters which distinguish the male from the female externally are called **secondary sex characters**.

Differences between Primary Sex Organs and Secondary Sex Organs	
Primary Sex Organs	Secondary Sex Organs
<ol style="list-style-type: none"> 1. They produce gametes. 2. They also secrete sex hormones. 3. Testes in male and ovaries in female are examples of primary sex organs. 	<ol style="list-style-type: none"> 1. They do not produce gametes. They are concerned with the conduction of gametes. 2. They do not secrete sex hormones. 3. Epididymes, vasa deferentia, penis, etc. are secondary sex organs in male and oviducts, uterus, etc. are examples of secondary sex organs in female.

Functions of Male Reproductive System

1. **Spermatogenesis.** The germinal epithelial cells of seminiferous tubules produce sperms.

2. **Male Sex hormones.** Leydig's cells (interstitial cells) produce male sex hormones (e.g., testosterone).

3. **Transfer of Sperms.** Copulatory organ (e.g., penis) transfers sperms into the vagina of the female during copulation.

Semen

Semen is a collection of secretions from the seminal vesicles, prostate gland and Cowper's glands and sperms from testes. Semen is ejected from the penis during ejaculation. A single ejaculation may contain 200 to 300 million spermatozoa (sperms) of which at least 60% sperms must have normal shape and size and at least 40% of them must show vigorous motility for normal fertility. Semen has a pH of 7.35 to 7.50; its alkalinity helps to neutralize the acidity of the urethra left from the passage of urine and protects the sperms from the acidity of the vagina. Infact fluid part of semen is called seminal plasma.

Hormonal Control of Male Reproductive System

The growth, maintenance and functions of the male reproductive organs are under the hormonal control as described below. GnRH is secreted by the hypothalamus. It stimulates the anterior lobe of the pituitary gland to secrete LH and FSH. In male LH is called interstitial cells stimulating hormone (ICSH) because it stimulates interstitial cells (Leydig's cells) of the testes to secrete androgens. **Testosterone** is the principal androgen. FSH stimulates Sertoli cells of the testes to secrete an **androgen-binding protein (ABP)** that concentrates testosterone in the seminiferous tubules. Sertoli cells also secrete a protein hormone called **inhibin** which suppresses FSH synthesis. FSH acts directly on spermatogonia to stimulate sperm production.

Onset of Puberty in Human Male

Puberty is a period when reproductive organs start functioning. Puberty in human male is attained between 13–16 years. Hormone testosterone plays a significant role in the onset of puberty. Gonadotropin releasing hormone (GnRH) is secreted by the hypothalamus, which stimulates the anterior lobe of the pituitary gland to secrete luteinising hormone (LH) and follicle stimulating hormone (FSH). In males LH may be called interstitial cells stimulating hormone (ICSH) because it stimulates the interstitial cells (Leydig's cells) of the seminiferous tubules of the testes to secrete androgens. Testosterone is principal androgen which brings about the growth of the secondary sex organs and development of secondary sexual characters. This is onset of puberty in human males.

Male Sex Act

It involves three phases erection of the penis, copulation and subsidence of erection.

(i) **Erection of Penis.** It is caused by rush of blood into the sinuses of its spongy tissue on sexual excitement. Stiffness of the penis is due to the hydraulic pressure of blood filling the sinuses.

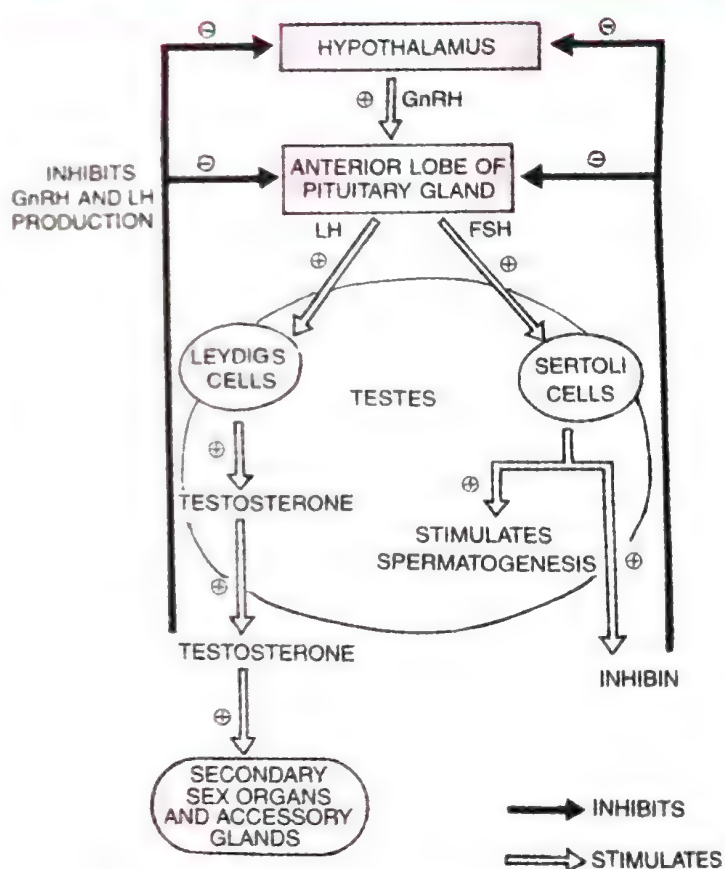


Fig. 3.8. Hormonal control of male reproductive system.

(ii) **Coitus (Copulation)**—Sexual intercourse. The penis is inserted into the vagina of the female. Friction due to rhythmic movements of the penis stimulates release of semen into the urethra. This is called **emission**. Then the wavelike contractions of the muscles at the base of the penis cause forceful discharge of the semen into the vagina. This is called **ejaculation**.

At the peak of sexual stimulation a pleasurable sensation occurs which is called **orgasm**. It generally lasts only a few seconds.

(iii) **Subsidence of Erection**. After ejaculation, the arterioles to the penis contract. This reduces the blood flow to the penis which subsides erection of the penis.

Disorders of Male Reproductive System

1. **Benign Prostatic Hypertrophy (BPH)**. This is the enlargement of the prostate gland. It often occurs in old age. It compresses the urethra, causing frequent night urination (**nocturia**) or difficult or painful micturition. Untreated BPH may lead to kidney damage.

2. **Prostate cancer**. Cancer of the prostate gland is an extremely common malignancy, accounting for 2 to 3% of male deaths. Malignant prostate cells are usually stimulated by testosterone, so treatment often involves removal of the testes, thereby preventing production of the hormone. The most commonly used marker enzyme in clinical diagnosis of prostate cancer is **acid phosphatase**.

3. **Impotence**. Impotence is the inability to achieve or hold an erection of penis long enough to complete sexual intercourse. Psychological factors are most often cited as causes, but neurological disorders, vascular disorders, and syphilis can also cause impotence. Certain drugs (e.g., Viagra) are available to cure impotency.

4. **Sterility**. In males sterility is the inability of a sperm to fertilize an ovum.

5. **Inguinal hernia**. Tearing of inguinal tissue may result in the protrusion of a part of intestine into the scrotum. This condition is called **inguinal hernia**.

6. **ADAM (Androgen Deficiency in Ageing Males)**. It is also called **andropause (male menopause)**. It is due to reduced production of testosterone. Unlike female menopause there is no specific age for males.

7. **Cryptorchidism** (*Crypto* - hidden, *Orchid* - testis). It is a condition in which the testes do not descend into the scrotum. It is caused by deficient secretion of testosterone by foetal testes. Retention of testes in the abdominal cavity results in sterility.

8. **Hydrocoele**. It is a collection of fluid, usually in the tunica vaginalis of the testis.

HUMAN FEMALE REPRODUCTIVE SYSTEM

The female reproductive system consists of the ovaries, uterine tubes, uterus, vagina, and the external genitalia. Because of their role in nourishing the offspring, the breasts or mammary glands are considered part of the female reproductive system.

1. **Ovaries**. Ovaries are **primary sex organs** in human female. The ovaries are paired structures located in the upper pelvic cavity. Each ovary, shaped like an unshelled almond, is about 2 to 4 cm in length. The **ovarian ligament** (ligament of ovary) attaches the ovary to the uterus. The **broad ligament** of the uterus which is itself part of the parietal peritoneum attaches to the ovary by a double layered fold of peritoneum called the **mesovarium**. As we shall see later, the ovaries are responsible for producing female sex hormones and ova. The ovary consists of the following parts.

(i) The ovary is covered by a layer of cubical epithelium called the **germinal epithelium**. The germinal epithelium is covered by **visceral peritoneum**.

(ii) Beneath the epithelium is the **tunica albuginea**—a layer of connective tissue and underlying it is the ovarian stroma.

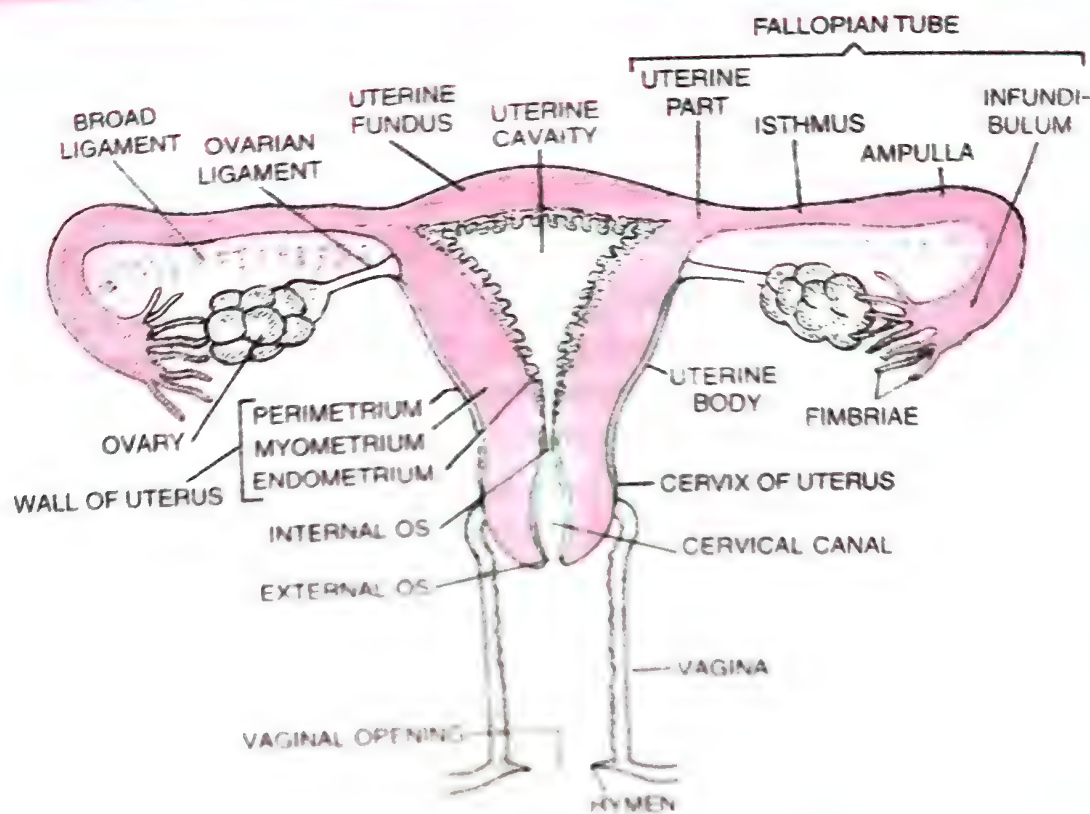


Fig. 3.9. Female reproductive system

(iii) The **ovarian stroma** consists of a dense outer layer called the **cortex** and a less dense inner portion called the **medulla**.

(iv) No more oogonia are formed and added after birth. Oogonia (egg mother cells) divide by mitosis forming **primary oocyte**. Each primary oocyte then gets surrounded by a layer of granulosa cells called **primary follicle**. A large number of these follicles degenerate during the phase from birth to puberty. Therefore, at puberty only 60,000–80,000* primary follicles are left in each ovary. The primary follicles are surrounded by more layers of granulosa cells and called **secondary follicles**. The secondary follicle soon changes into a **tertiary follicle** which is characterized by a fluid filled cavity called **follicular antrum** (Gr. *antron* = a cave). The tertiary follicle is further converted into mature follicle or **Graafian follicle**.

(v) Interspersed throughout the cortex are many **ovarian follicles** (also called **Graafian follicles**) in different stages of development. The ovarian follicle comprises the following parts.

A follicle (Fig. 3.11) consists of an **oocyte** covered by a homogenous membrane the **zona pellucida**. When the surrounding cells form a single layer they are called **follicular cells**. Later in development when they form several layers, they are referred to as **granulosa cells**. The surrounding cells nourish the developing oocyte and begin to secrete oestrogens as the follicle grows larger. The zona pellucida is surrounded by follicular cells called **membrana granulosa**. The follicle has an eccentric **follicular cavity** or **follicular antrum** filled with a fluid, the **follicular fluid** or **liquor folliculi**. A solid mass of the follicular cells

*As per Jeffcoate (Principles of Gynaecology) 300000–500000 ova/follicles are found at puberty.

that surrounds the developing ovarian follicle is called the **cumulus oophoricus*** formed by granulosa cells. It projects into the follicular cavity (= follicular antrum). Later, the granulosa cells lying in close vicinity of the oocyte and zona pellucida, become elongated to form the **corona radiata**. The membrana granulosa is surrounded by the **theca interna** (theca = cover) and **theca externa**.

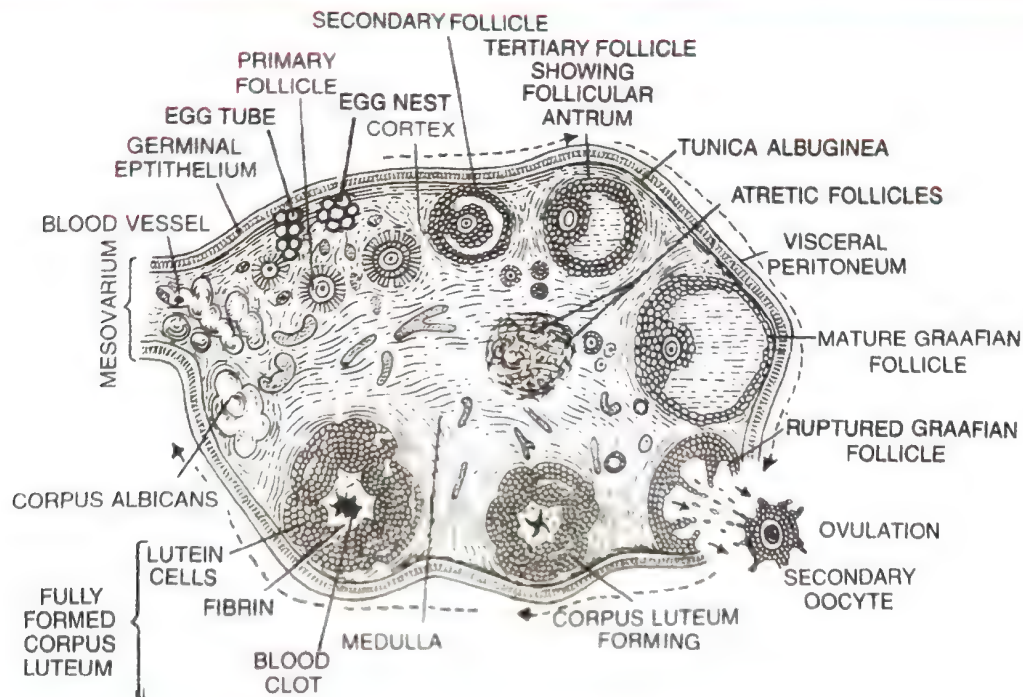


Fig. 3.10. A section of a mammalian ovary.

The total number of follicles in each ovary of a normal young adult woman is about 60,000 to 80,000. Many ovarian follicles (during primary oocyte stage) undergo degeneration. This degenerative process of follicles is called **follicular atresia** and such follicles are known as **atretic follicles**.

The release of secondary oocyte from the ovary is called **ovulation**. It occurs due to the rupturing of ovarian follicle and the wall of the ovary. Generally one secondary oocyte is released in each menstrual cycle (average duration 28 days) by alternate ovaries. Only about 450 secondary oocytes (ova) are produced by a human female over the entire span of her reproductive life which lasts about 40–50 years of age (in some cases 45–55 years).

In addition to releasing an oocyte, the follicle also produces hormones. While the follicle is maturing, some of the follicular cells produce **oestrogens**, mainly **estradiol**.

(v) After ovulation many of the follicular cells remain in the collapsed follicle on the

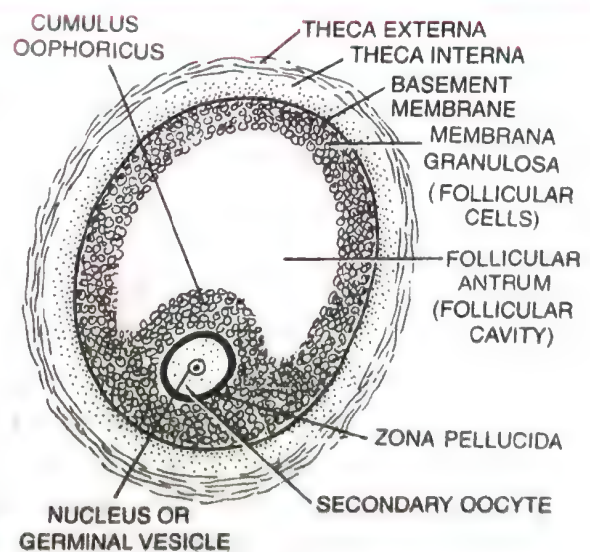


Fig. 3.11. Mature Graafian follicle.

*Also called cumulus oophorus or cumulus ovaricus.

surface of the ovary. The antrum (cavity) of the collapsed follicle fills with a partially clotted fluid. The follicular cells enlarge and fill with a yellow pigment, **lutein**. Such a follicle is called a **corpus luteum**— literally, yellow body. The lutein cells secrete small amount of estradiol hormone and significant amount of the **progesterone** hormone. Corpus luteum also secretes **relaxin** hormone.

Differences between Graafian Follicle and Corpus luteum	
<i>Graafian Follicle</i>	<i>Corpus luteum</i>
1. It consists of an oocyte, zona pellucida, cellular membranous granulosa surrounded by the theca interna and the externa.	1. It consists of luteum cells, fibrin and blood clot.
2. It contains follicular antrum (follicular cavity) filled with follicular fluid.	2. It contains blood clot.
3. It is formed by the germinal epithelium of the ovary.	3. It is formed after the release of secondary oocyte from the Graafian follicle.
4. Its granular cells secrete oestrogens.	4. It secretes progesterone.

(vi) Degenerated part of the corpus luteum is called **corpus albicans**, literally meaning white body. Infact it is a white scar-like area.

Functions of Ovaries. Production of ova and secretion of female sex-hormones.

Two Fallopian tubes (oviducts), uterus and vagina constitute the **female accessory ducts**.

2. **Fallopian tubes (oviducts).** Each Fallopian tube is about 10–12 cm long and consists of the following parts.

(i) The **infundibulum** is a dilated trumpet-like portion opening into the peritoneal cavity. The end of the tube has finger-like projections called **fimbriae** which help in collection of the ovum after ovulation.

(ii) **The ampulla** is the widest and longest part of the Fallopian tube.

(iii) **The isthmus** is the short, narrow thick-walled portion that follows the ampulla.

(iv) **The uterine part** passes through the uterine wall and communicates with the uterine cavity.

Functions of Fallopian Tubes. The Fallopian tube conveys the ovum from the ovary to the uterus. It is done by peristalsis. Fertilization of the ovum generally takes place in the upper portion of the Fallopian tube (ampulla).

3. **Uterus (= Metra or Hystera or Womb).** The uterus is a hollow muscular and inverted pear shaped structure. It lies in the pelvic cavity between the urinary bladder and the rectum. It comprises three parts : (i) The **fundus** is the upper dome-shaped part of the uterus above the openings of the uterine parts of the Fallopian tubes. (ii) **Cornua** (sing. Cornu). They are the upper corners where the oviducts enter the uterus. (iii) The **body (corpus)** is the main part which is narrowest inferiorly where it continues with the cervix. (iv) The **cervix** is the part which joins the anterior wall of the vagina and opens into it. The cavity of the cervix is called **cervical canal**. The cervix communicates above with the body of the uterus by an aperture called **internal os** and with the vagina below by an opening, the **external os**.

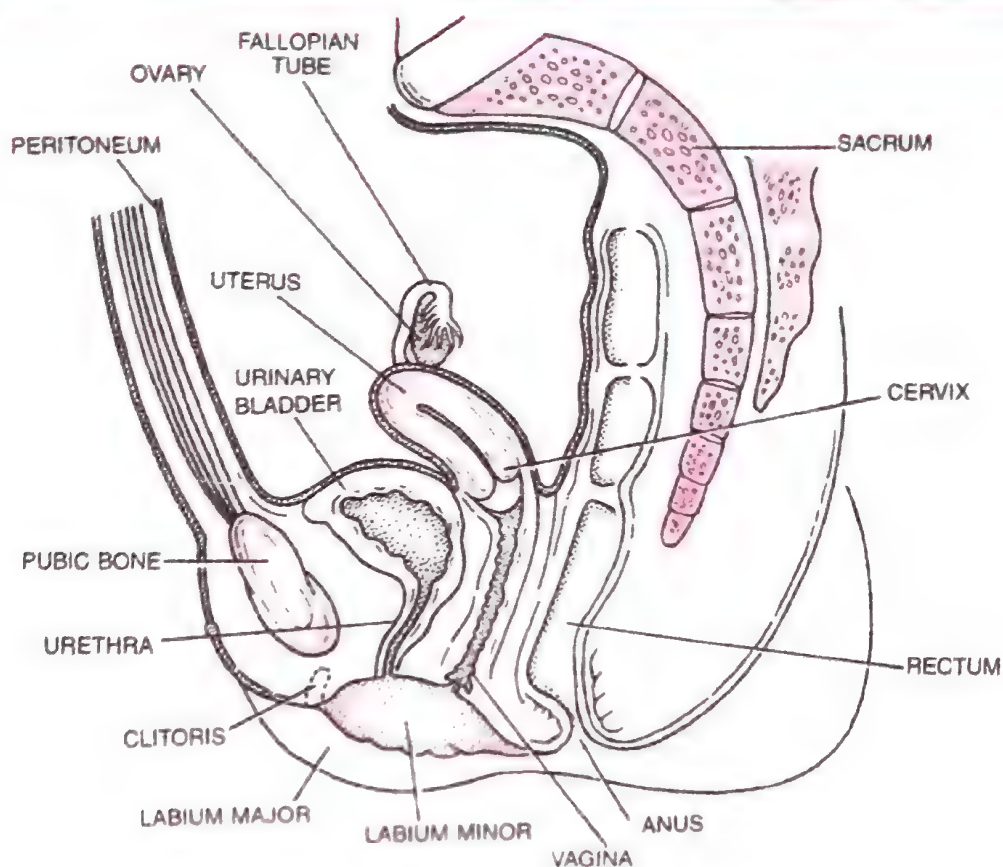


Fig. 3.12. Female reproductive system, in lateral view.

The walls of the uterus are composed of three layers of tissues. The **perimetrium** is an outer thin covering of peritoneum. The **myometrium** is a middle thick layer of smooth muscle fibres which shows strong contraction during delivery of the baby. The **endometrium** is inner glandular layer that lines the uterine cavity. The endometrium undergoes cyclical changes during menstrual cycle.

Differences between Endometrium and Myometrium

Endometrium	Myometrium
<ol style="list-style-type: none"> 1. It is inner glandular layer of the wall of the uterus. 2. It undergoes cyclic changes during menstrual cycle. Implantation of blastocyst takes place on endometrium. 	<ol style="list-style-type: none"> 1. It is thick muscular middle layer of the wall of the uterus. 2. It is involved in the uterine movements.

Functions of Uterus. After puberty the uterus goes through the **menstrual cycle**. If the fertilization has taken place, the embryo gets attached to the uterine wall where it is nourished and protected. At the end of the gestation period **labour** begins and concludes when the child is born.

4. **Vagina.** The vagina is a tube, about 10 cm long, that extends from the cervix to the outside of the body. It is easily stretched. The opening of the vagina, called the **vaginal orifice (vaginal opening)**, is partially covered by a membrane called the **hymen**.

Functions of Vagina. It provides a passageway for the menstrual flow, serves as the receptacle for sperm during intercourse, and forms part of the birth canal during labour.

The hymen is often torn during the first coitus (intercourse). However, it can also be broken by a sudden fall or jolt, active participation in some sports like horse back riding, bicycling, etc. In some women the hymen remains even after coitus. In fact, the presence or absence of hymen is not a reliable indicator of virginity.

5. External genitalia (Vulva). The external genitalia are collectively called the **vulva** that consists of the following structures.

(i) **Mons pubis.** It is the anterior most portion of the external genitalia which is a cushion of fatty tissue covered by skin and pubic hair.

(ii) **Clitoris.** Posterior to the mons pubis is the clitoris which is **homologous to glans penis** of the male. It contains erectile tissue. Clitoris differs from male penis as it is very much reduced in size and does not have any passage (it is solid structure, however, male penis has urethra).

There are present **urethral orifice** (urethral opening) and **vaginal orifice** (vaginal opening) in the mid-line of the vulva.

(iii) **Labia majora.** These are two large fleshy folds of skin which form the boundary of vulva. They are partly covered by pubic hair and contain large number of sebaceous (oil) glands. The labia majora are considered **homologous to the scrotum of the male**.

(iv) **Labia minora.** These are two smaller folds of skin which lie under the labia majora. Labia minora are **homologous to penile urethra** of male. Posteriorly the labia minora are fused together to form the **fourchette**. They also contain numerous sebaceous glands. The area between the labia minora is called the **vestibule**. Vestibule is **homologous to membranous urethra of male**.

(v) **Perineum.** It is the area which extends from the fourchette to the anus.

Glands. Vestibular glands. These are of two types. The **lesser vestibular glands** (= **Paraurethral glands** or **glands of Skene**) are numerous minute glands that are present on either side of the urethral orifice (opening). These glands are **homologous to the male prostate** and secrete mucus. The **greater vestibular glands** (= **Bartholin's glands**) are paired glands, situated one on each side of the vaginal orifice (opening). These glands are **homologous to the bulbo-urethral (Cowper's) glands of male** and secrete viscid fluid that supplements lubrication during sexual intercourse.

6. Breasts. The breasts are two rounded prominences that lie over the pectoralis major muscles on the front wall of the thorax. They are also present in the male but only in a rudimentary form. In the female, they are undeveloped until puberty. At puberty in females

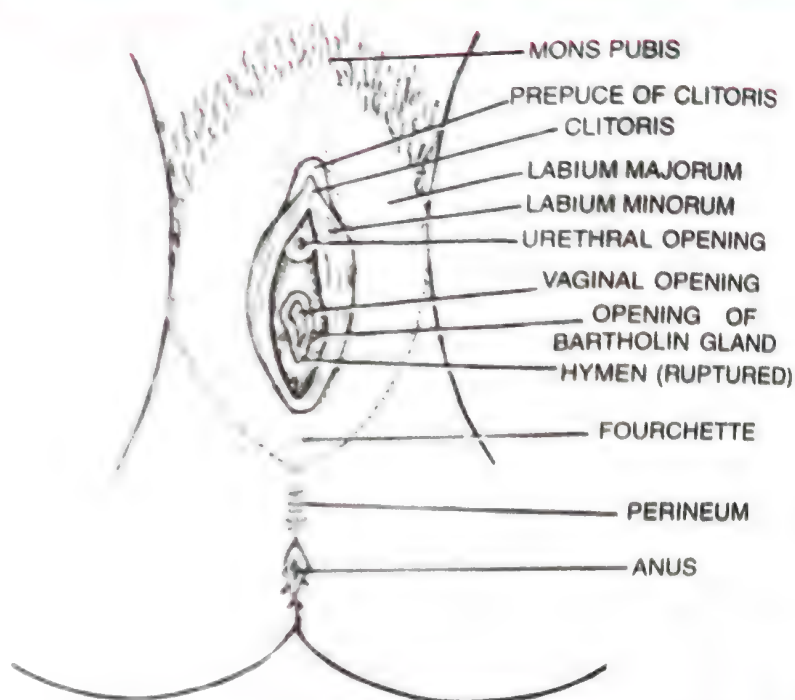


Fig 3.13. The external genitalia in the human female.

they begin to develop under the influence of oestrogen and progesterone hormones. Externally, each breast has a projection, the **nipple** surrounded by a circular pigmented area of skin (deep pink to light brown) called **areola**. On the surface of the areola there are numerous sebaceous glands called **areolar glands**.

Internally, the breast consists of the glandular tissue forming **mammary glands**, the fibrous tissue (connective tissue) and the fatty or adipose tissue. Mammary glands are modified sweat glands.

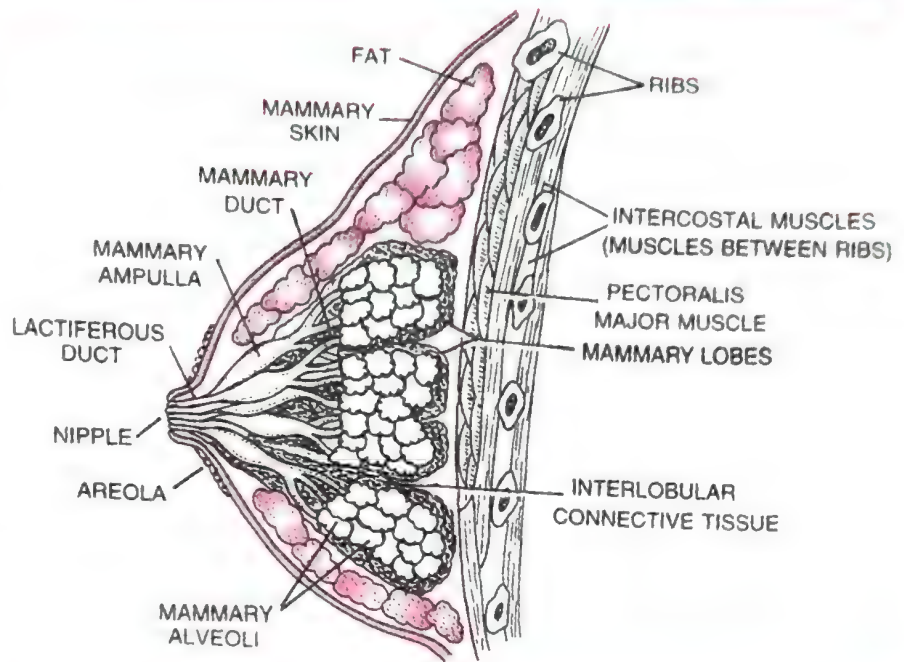


Fig. 3.14. Female's breast in sagittal section.

(a) The **glandular tissue** comprises about 15–20 **mammary lobes** in each breast. Each lobe is made up of a number of grapelike clusters of milk secreting structures termed **alveoli**. When milk is produced it passes from the alveoli into the **mammary tubules** and then into the **mammary ducts**. Near the nipple, mammary ducts expand to form **mammary ampullae** (= **lactiferous sinuses**) where some milk may be stored before going to **lactiferous ducts**. Each lactiferous duct typically carries milk from one of the lobes to exterior.

(b) The **fibrous tissue** (connective tissue) supports the alveoli and the ducts.

(c) The **fatty or adipose tissue** is found between the lobes and covers the surface of the gland. The amount of the adipose tissue determines the size of the breasts.

Main functions of the mammary glands are secretion and ejection (release) of milk. These functions are called **lactation**. Lactation is associated with pregnancy and child birth. Milk production is stimulated largely by the hormone **prolactin** secreted by anterior lobe of the pituitary gland. The ejection of milk is stimulated by the hormone **oxytocin**, released from the posterior lobe of the pituitary gland.

Human milk consists of water and organic and inorganic substances. Its main constituents are **fat** (fat droplets), **casein** (milk protein), **lactose** (milk sugar), mineral salts (sodium, calcium, potassium, phosphorous, etc.) and vitamins. Milk is poor in iron content. Vitamin C is present in very small quantity in milk. The process of milk secretion is regulated by the nervous system. It is also influenced by the psychic state of the mother. The process of milk production is also influenced by hormones of the pituitary gland (already mentioned), the ovaries and other endocrine glands. A nursing woman secretes 1 to 2 litres of milk per day.

Inhibitory Peptide. Milk contains an inhibitory peptide. If the mammary glands are not fully emptied the peptide accumulates and inhibits milk production.

Functions of Female Reproductive System

1. Germinal epithelial cells of the ovary produce ova (**oogenesis**).
2. **Fertilization** takes place in the Fallopian tube (oviduct).
3. After puberty the uterus goes through the **menstrual cycle**.

4. **Implantation and prenatal growth** take place in the uterus.
5. The vagina receives the seminal fluid during **copulation**.
6. **Parturition** (process of birth of child) is also important function of the female reproductive system.
7. Mammary glands of the female secrete **milk** after parturition.

Hormonal Control of Female Reproductive System

The growth, maintenance and functions of the female reproductive organs are under the hormonal control as described below.

GnRH is secreted by the hypothalamus which stimulates the anterior lobe of pituitary gland to secrete luteinising hormone (LH) and FSH. FSH stimulates the growth of the ovarian follicles and also increases the development of egg/oocyte within the follicle to complete the meiosis I to form secondary oocyte. FSH also stimulates the formation of oestrogens. LH stimulates the corpus luteum to secrete progesterone. Rising level of progesterone inhibits the release of GnRH, which, in turn, inhibits the production of FSH, LH and progesterone.

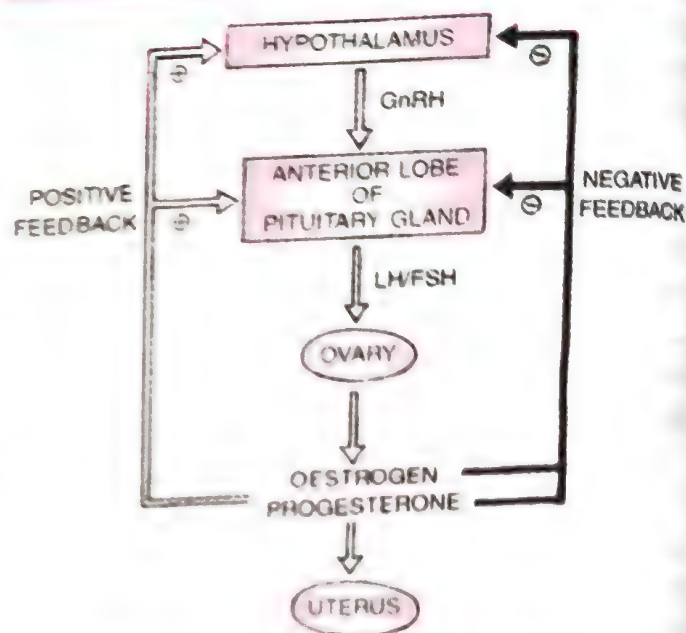


Fig 3.15 Hormonal control of female reproductive system.

Onset of Puberty in the Human Females

Females attain puberty at about the age of thirteen years. At this time, the pituitary gland begins producing follicle-stimulating hormone (FSH). The FSH induces the development of ovaries, which in turn produce the hormone oestrogen. This hormone is responsible for the development of the female secondary sex characters, including a change in voice and the development of external genitalia, breasts, body hair, pubic hair, and the feminine shape. This shape means a widening of the pelvis and deposits of fat in thighs, buttocks and face.

Sexual Arousal. When inactive sexual behaviour changes to active sexual behaviour, it is called sexual arousal. In sexually aroused female, the increased blood supply to clitoris, labia minora and vagina makes these organs swollen due to their erectile tissue. Bartholin's glands secrete mucus for lubricating the vestibule to facilitate intercourse. Orgasm is due to rhythmic spasms of the muscles surrounding the vagina.

Disorders of Female Reproductive System

1. **Breast Cancer.** Breast cancer is rarely seen before the age of thirty. The standard treatment for breast cancer is mastectomy (removal of breast).
2. **Cervical Cancer.** Cervical cancer may be treated by radiation or surgery.
3. **Oophorocystosis (Ovarian Cysts).** Ovarian cysts are fluid filled tumours of the ovary. Such cysts sometimes rupture and regress (get smaller) during pregnancy. In old women they are surgically removed.
4. **Ectopic Pregnancy.** It is implantation of embryo at a place other than uterus, generally in the oviduct.
5. **Oophoritis.** It is inflammation of ovary, usually caused by an infection.

6. **Endometriosis.** It is the growth of endometrial tissue outside the uterus. Symptoms include premenstrual pain or unusual menstrual pain. Treatment is usually hormone therapy or surgery. Endometriosis disappears at menopause or when the ovaries are removed.

7. **Menstrual disorders.** These include the following (i) **Amenorrhea** is the absence of menstruation (ii) **Menorrhagia** is excessive menstruation (iii) **Dysmenorrhea** is painful menstruation.

8. **Infertility.** Infertility in women is the inability to become pregnant. It may be due to failure to ovulate or to some anatomical factor that prevents the union of egg (ovum) and sperm.

GAMETOGENESIS

Gametogenesis is the process by which male and female sex cells or gametes, *i.e.*, sperms and ova are formed respectively in the male and female gonads (testes and ovaries). The gametes differ from all other cells (= somatic cells) of the body as their nuclei contain only half the number of chromosomes found in the nuclei of somatic cells.

Meiosis forms the most significant part of process of gametogenesis. Gametogenesis for the formation of sperms is termed as **spermatogenesis**, while that of ova is called **oogenesis**. Both spermatogenesis and oogenesis comprise similar phases of sequential changes *viz.*, (i) multiplication phase, (ii) growth phase and (iii) maturation phase.

Spermatogenesis

The process of formation of sperms is called spermatogenesis. It occurs in the **seminiferous tubules** of the testes. The seminiferous tubules are lined by **germinal epithelium**. The germinal epithelium consists largely of cuboidal **primary** or **primordial germ cells** (PGCs) and contains certain tall somatic cells called **Sertoli cells** (= nurse cells). Spermatogenesis includes formation of spermatids and formation of spermatozoa.

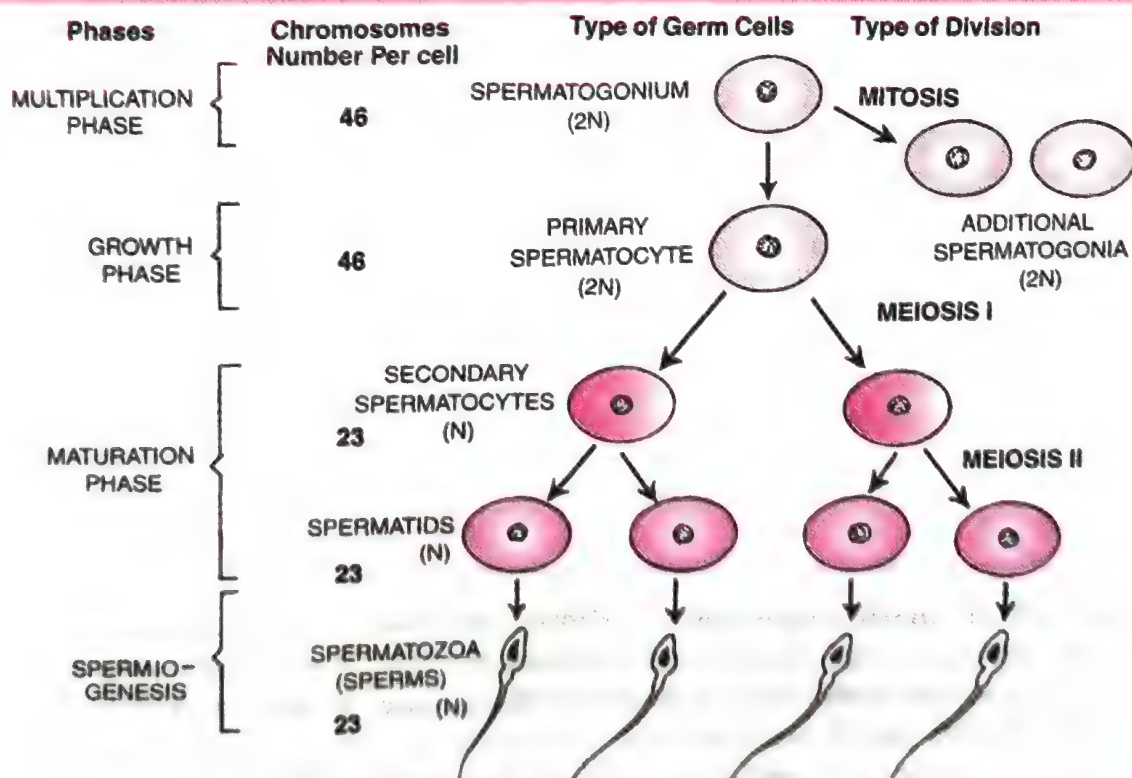


Fig. 3.16. Stages in spermatogenesis (diagrammatic).

(i) **Formation of Spermatids.** It includes the following phases.

(a) **Multiplication Phase.** At sexual maturity, the undifferentiated primordial germ cells divide several times by mitosis to produce a large number of spermatogonia (Gr. *sperma* = seeds, *gonos* = generation). Spermatogonia (2N) are of two types: type A spermatogonia and type B spermatogonia. **Type A spermatogonia** serve as the stem cells which divide to form additional spermatogonia. **Type B spermatogonia** are the precursors of sperms.

(b) **Growth Phase.** Each type B spermatogonium actively grows to a larger **primary spermatocyte** by obtaining a nourishment from the nursing cells.

(c) **Maturation Phase.** Each primary spermatocyte undergoes two successive divisions, called **maturation divisions**. The first maturation division is reductional or meiotic. Hence, the primary spermatocyte divides into two haploid daughter cells called **secondary spermatocytes**. Both secondary spermatocytes now undergo second maturation division which is an ordinary mitotic division to form, four haploid **spermatids**, by each primary spermatocyte.

(ii) **Formation of Spermatozoa from Spermatids (Spermiogenesis).** The transformation of spermatids into spermatozoa is called **spermiogenesis** or **spermateliosis**. The spermatozoa are later on known as sperms. Thus four sperms are formed from one spermatogonium.

After spermiogenesis sperm heads become embedded in the Sertoli cells and are finally released from the seminiferous tubules by the process called **spermiation**.

Hormonal Control of Spermatogenesis. Spermatogenesis is initiated due to increase in gonadotropin-releasing hormone (GnRH) by the hypothalamus. GnRH acts on the anterior lobe of pituitary gland to secrete luteinizing hormone (LH) and follicle stimulating hormone (FSH). LH acts on the Leydig's cells of the testes to secrete testosterone. FSH acts on Sertoli cells of the seminiferous tubules of the testes to secrete an androgen binding protein (ABP) and inhibin. ABP concentrates testosterone in the seminiferous tubules. Inhibin suppresses FSH synthesis. FSH acts on spermatogonia to stimulate sperm production.

Differences between spermatogenesis and spermiogenesis	
Spermatogenesis	Spermiogenesis
1. It is the process of the formation of haploid spermatozoa (sperms) from the undifferentiated diploid primordial germ cells of the testes.	1. It is the process of the transformation of spermatids into spermatozoa (sperms).
2. It involves multiplication phase, growth phase, maturation phase and differentiation phase.	2. It involves only differentiation phase, therefore, it is a part of spermatogenesis.
3. A spermatogonium produces four spermatozoa (sperms).	3. One spermatid develops into one spermatozoon.

Significance of Spermatogenesis. (i) During spermatogenesis, one spermatogonium produces four sperms. (ii) Sperms have half the number of chromosomes. After fertilization, the diploid chromosome number is restored in the zygote. It maintains the chromosome number of the species. (iii) During meiosis I crossing over takes place which brings about variation. (iv) Spermatogenesis occurs in various organisms. Thus it supports the evidence of the basic relationship of the organisms.

Spermatozoon (Sperm; Fig. 3.17)

The sperms are microscopic and motile cells. Sperms remain alive and retain their ability to fertilize an ovum (egg) from 24 to 48 hours after having been released in the female genital tract. A typical mammalian sperm consists of a head, neck, middle piece and tail.

(i) **Head.** It contains anterior small **acrosome** and posterior large nucleus. Acrosoma is formed from Golgi body of the spermatid. Acrosome contains hyaluronidase proteolytic enzymes which are popularly known as **spermlysins** that are used to contact and penetrate the egg (ovum) at the time of fertilization.

(ii) **Neck.** It is very short and is present between the head and middle piece. It contains the **proximal centriole** towards the nucleus which plays a role in the first cleavage of the zygote and the **distal centriole** which gives rise to the axial filament of the sperm.

(iii) **Middle piece.** The middle piece of human sperm contains the mitochondria coiled round the axial filament called **mitochondrial spiral**. They provide energy for the movement of the sperm. So it is the "power house of the sperm". At the end of the middle piece there is a **ring centriole (annulus)** with unknown function.

Posterior half of nucleus, neck and middle piece of sperm are covered by a sheath called **manchette**.

(iv) **Tail.** The tail is several times longer than the head. In its most part called main piece, the axial filament is surrounded by a thin layer of cytoplasm. The part behind the mainpiece is called **end piece** which consists of naked filament alone. The sperm swims about by its tail in a fluid medium.

Oogenesis (Fig. 3.18)

The process of formation of a mature female gamete (ovum) is called oogenesis. It occurs in the ovaries (female gonads). It consists of three phases : multiplication, growth and maturation.

(a) **Multiplication phase.** In the foetal development, certain cells in the germinal epithelium of the ovary of the foetus are larger than others. These cells divide by mitosis, producing a couple of million **egg mother cells** or **oogonia** in each ovary of the foetus. No more oogonia are formed or added after birth. The oogonia multiply by mitotic divisions forming the **primary oocytes**.

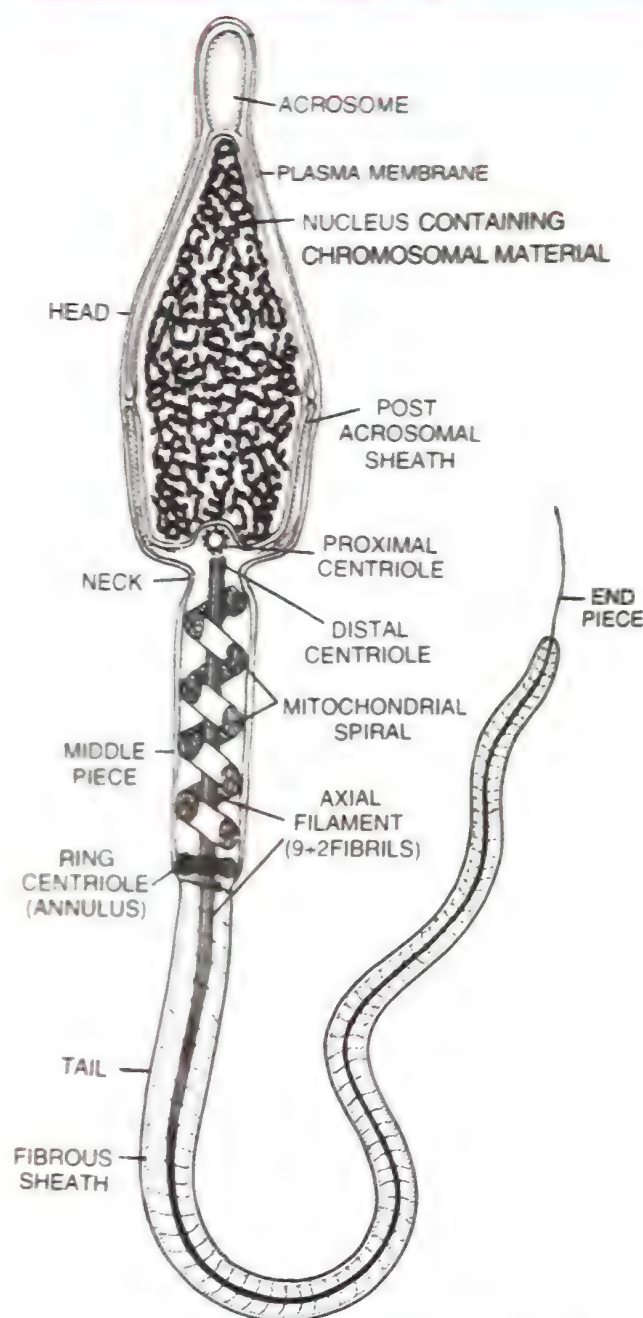


Fig. 3.17. A mammalian spermatozoon as seen under electron microscope.

(b) **Growth phase.** This phase of the primary oocyte is very long. It may extend over many years. The oogonium grows into a large **primary oocytes**. Each primary oocyte then gets surrounded by a layer of granulosa cells to form **primary follicle**. A large number of these follicles degenerate during the period from birth to puberty. So at puberty only 60,000–80,000 primary follicles are left in each ovary. The fluid filled cavity of the follicle is called **antrum**.

(c) **Maturation phase.** Like a primary spermatocyte, each primary oocyte undergoes two maturation divisions, first meiotic and the second meiotic. The results of maturation divisions in oogenesis are, however, very different from those in spermatogenesis. In the first, meiotic division, the primary oocyte divides into two very unequal haploid daughter cells—a large **secondary oocyte** and a very small **first polar body** or **polocyte**. In the second maturation division, the first polar body may divide to form two second polar bodies. The secondary oocyte again divides into unequal daughter cells, a large **ootid** and a very small **second polar body**. The ootid grows into a functional haploid **ovum**. Thus from one oogonium, one ovum and three polar bodies are formed. The ovum, is the actual female gamete. The polar bodies take no part in reproduction and, hence, soon degenerate.

In human beings, ovum is released from the ovary in the secondary oocyte stage. The maturation of secondary oocyte is completed in the mother's oviduct (Fallopian tube) usually after the sperm has entered the secondary oocyte for fertilization.

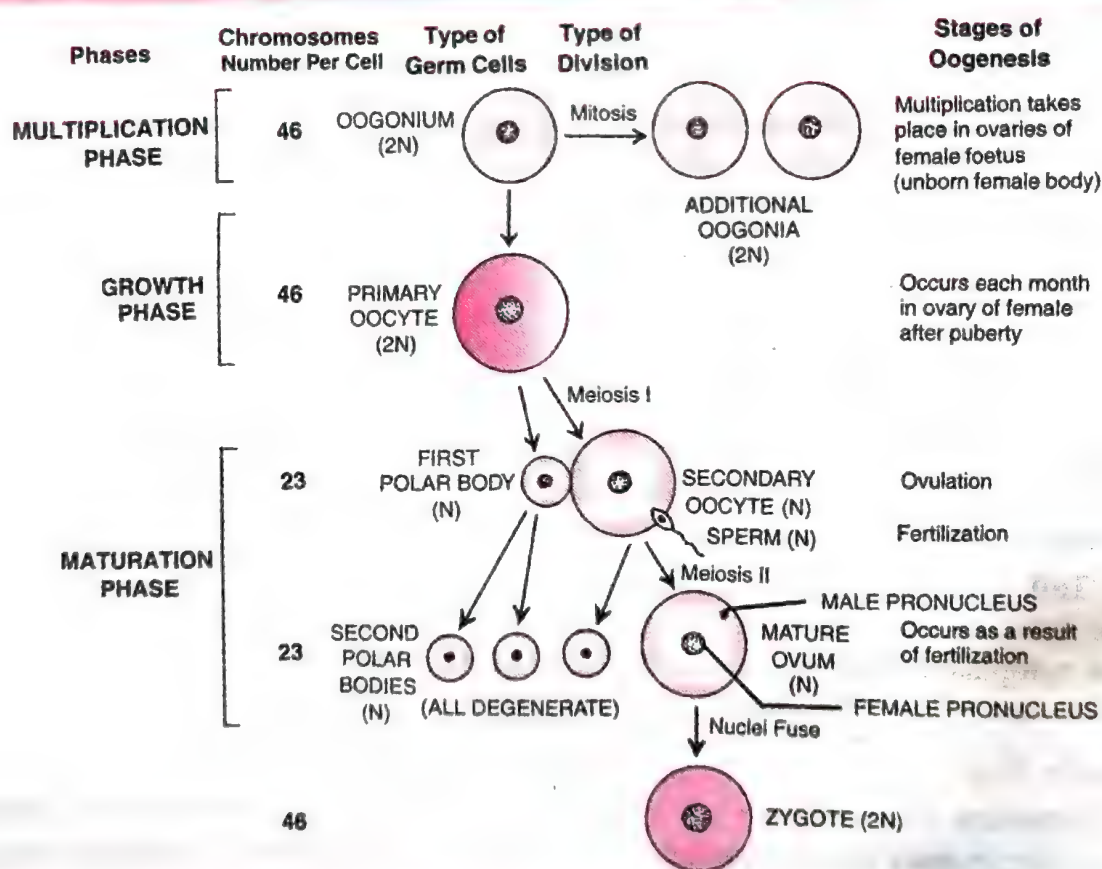


Fig. 3.18. Stages in oogenesis (diagrammatic).

In humans (and most vertebrates), the first polar body does not undergo meiosis II, whereas the secondary oocyte proceeds as far as the metaphase stage of meiosis II. However, it then stops advancing any further; it awaits the arrival of sperm for completion of meiosis II. Entry of the sperm restarts the cell cycle breaking down MPF (M-phase

promoting factor) and turning on **APC** (Anaphase promoting complex). Completion of meiosis II converts the secondary oocyte into a fertilized ovum (egg) or zygote (and also a second polar body).

Hormonal Control of Oogenesis. GnRH secreted by the hypothalamus stimulates the anterior lobe of pituitary gland to secrete LH and FSH. FSH stimulates the growth of Graafian follicles and also the development of egg/oocyte within the follicle to complete the meiosis I to form secondary oocyte. FSH also stimulates the formation of oestrogens. LH induces the rupture of the mature Graafian follicle and thereby the release of secondary oocyte. Thus LH causes ovulation. In brief ovulation in human beings may be defined as the release of the secondary oocyte from the Graafian follicle. The remaining part of the Graafian follicle is stimulated by LH to develop into corpus luteum ("yellow body").

The rising level of progesterone inhibits the release of GnRH, which in turn, inhibits production of FSH, LH and progesterone.

Significance of Oogenesis

- (i) One oogonium produces one ovum and three polar bodies.
- (ii) Polar bodies have small amount of cytoplasm. It helps to retain sufficient amount of cytoplasm in the ovum which is essential for the development of early embryo. Formation of polar bodies maintains half number of chromosomes in the ovum.
- (iii) During meiosis first crossing over takes place which brings about variation.
- (iv) Oogenesis occurs in various organisms. Therefore, it supports the evidence of basic relationship among the organisms.

Differences between Spermatocytes and Oocytes	
<i>Spermatocytes</i>	<i>Oocytes</i>
1. Primary spermatocytes are formed from the spermatogonia in the seminiferous tubules of testes by mitosis.	1. Primary oocytes are formed from the oogonia in the ovary of the foetus.
2. Each primary spermatocyte undergoes meiosis I and forms the two haploid secondary spermatocytes.	2. Each primary oocyte undergoes meiosis I and forms haploid secondary oocytes and haploid first polar body.
3. Each secondary spermatocyte undergoes meiosis II and forms two haploid spermatids.	3. The secondary oocyte undergoes meiosis II and forms one ovum and one second polar body.
4. Each primary spermatocyte forms four haploid spermatids.	4. Each primary oocyte forms one ovum and three polar bodies.

OVULATION

In humans, ovum is released from the ovary in the secondary oocyte stage. Thus in human being, ovulation is the release of the secondary oocyte from the ovary. The wall of the ovary gets ruptured to release the oocyte. *In humans ovulation occurs about 14 days before the onset of the next menstruation. Ovulation is induced by LH.* The maturation of the ovum is completed in the mother's Fallopian tube usually after the sperm has entered the secondary oocyte during fertilization.

OVUM (Fig. 3.19)

The mature ovum or a female gamete is spherical in shape. The human ovum is almost free of yolk and is said to be **alecithal**. Its cytoplasm is called **ooplasm** containing large

nucleus, termed the **germinal vesicle**.

The nucleus contains a prominent nucleolus. There are no centrioles in the ovum. The cytoplasm is enveloped by the **plasma membrane** (cell membrane). Very small vesicles called **cortical granules** are present under the plasma membrane. A narrow **perivitelline space** is present outside the plasma membrane. Just outer to perivitelline space, there is thick, acellular **zona pellucida**; probably secreted by the follicular cells. Outer to the zona pellucida there is very thick cellular **corona radiata**. The latter is formed of radially elongated follicular cells. The side of ovum which extrudes polar bodies is termed as **animal pole**. The opposite side is called **vegetal pole**.

Human ovum (egg) loses its ability to be fertilized about 24 hours after ovulation. In human beings ovum is released from the ovary as secondary oocyte.

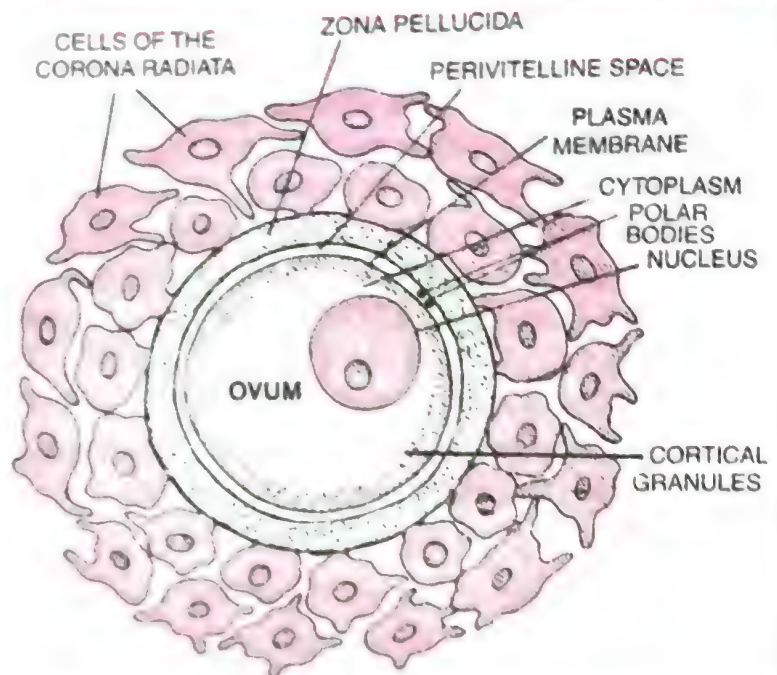


Fig. 3.19. An oocyte.

Differences between human Sperm and Ovum

Sperm	Ovum
<ol style="list-style-type: none"> 1. Sperms are produced in the testes. 2. Four sperms are formed from one spermatogonium. 3. It is externally differentiated into head, neck, middle piece and tail. 4. It has very small amount of cytoplasm. 5. Mitochondria form a spiral in the middle piece. 6. Sperm is motile and penetrates the ovum by releasing lysing enzymes (e.g., hyaluronidase). 	<ol style="list-style-type: none"> 1. Ova are produced in the ovaries. 2. Only one ovum is formed from one oogonium. 3. It is not externally differentiated into regions. 4. It has a large amount of cytoplasm called ooplasm. 5. Mitochondria are scattered in the ooplasm. 6. Ovum engulfs the sperm by forming a reception cone.

Similarities in Spermatogenesis and Oogenesis

1. Both processes consist of three main phases, viz., multiplication, growth and maturation phases.
2. In multiplication phase, the primordial germ cells of testes and ovaries proliferate mitotically, forming numerous gametogonia (spermatogonia/oogonia) in both processes.
3. In the growth phase, the cells accumulate food reserves and grow to primary gametocytes (spermatocytes/oocytes) in both processes.
4. Maturation phase in both processes comprises two successive divisions, first meiotic and second meiotic, resulting in the formation of secondary gametocytes and gametes respectively.

Differences between Spermatogenesis and Oogenesis

Spermatogenesis	Oogenesis
<ol style="list-style-type: none"> 1. It occurs in the testes. 2. Spermatogonia change to primary spermatocytes. 3. A primary spermatocyte divides to form two secondary spermatocytes. 4. A secondary spermatocyte divides to form two spermatids. 5. No polar body is formed. 6. A spermatogonium forms four spermatozoa. 7. Sperms are minute yolkless and motile. 8. It is generally completed in the testes and thus mature sperms are released from the testes. 	<ol style="list-style-type: none"> 1. It occurs in the ovaries. 2. Oogonia change to primary oocytes. 3. A primary oocyte divides to form one secondary oocyte and one polar body. 4. A secondary oocyte divides to form one ootid and one polar body. 5. Polar bodies are formed. 6. An oogonium forms one ovum. 7. Ova are much larger often with yolk and nonmotile. 8. It is often completed in the female reproductive tract or in many animals in water because oocytes are released from the ovaries.

DIFFERENTIATION OF GAMETES (SPERMS AND OVA)

Differentiation of Sperm. During spermiogenesis (transformation or differentiation of the spermatid into spermatozoon, *i.e.*, sperm) following changes occur.

(i) **Change in the nucleus.** The shape of the nucleus changes from the usual spherical to an elongated one.

(ii) **Acrosome formation.** The acrosome of the spermatozoon is derived from the Golgi body.

(iii) **Changes in the centrosome.** The centrosome of a spermatid consists of two centrioles. A depression is formed in the posterior surface of the nucleus and one of the two centrioles gets positioned in this depression with its axis at right angles to the main axis of the sperm. This is called **proximal centriole**. The other centriole called the **distal centriole** becomes placed behind the proximal centriole with its axis parallel to the longitudinal axis of the sperm. The distal centriole gives rise to the axial filament of the tail (flagellum) of the sperm for which it acts as a basal granule.

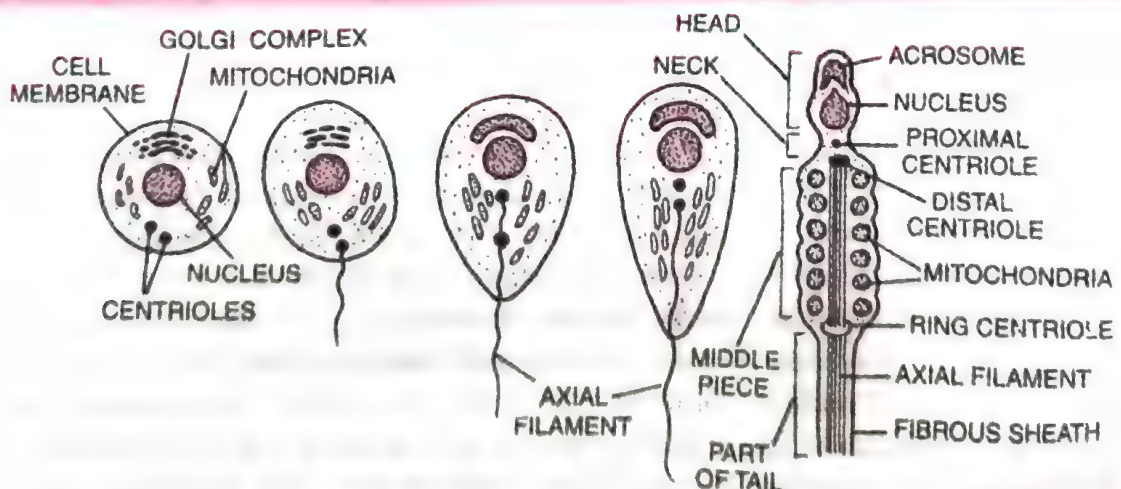


Fig. 3.20. Stages in Spermiogenesis.

- (iv) **Changes in the mitochondria.** In mammals, the mitochondria of the spermatid join to form mitochondrial spiral around the axial filament.
- (v) **Changes in the cytoplasm.** The abundant cytoplasm of the spermatid is reduced to a condensed layer.
- (vi) **Changes in plasma membrane.** It extends to surround the acrosome, nucleus, middle piece and main portion of the axial filament of the tail.
- (vii) **Ring centriole.** It is different from the centriole in its structure. Its function is unknown.
- (viii) **Axial filament.** As stated earlier it arises from the distal centriole.

Differentiation of Ova. Following changes occur during differentiation of oocyte into ovum.

- (i) **Changes in the nucleus.** The nucleus of the oocyte becomes enlarged mainly because of the production of a large amount of **nuclear sap**. In oocytes of some animals (e.g., amphibians, reptiles, birds etc.) lampbrush chromosomes appear. The nucleolus of a growing oocyte increases greatly in size.
- (ii) **Changes in cytoplasm**
 - (a) Mitochondria are fewer in young oocytes but increase in number during the growth of the oocyte.
 - (b) *Golgi bodies.* In mature oocytes they sometimes disappear completely. It indicates that Golgi bodies are changed to some other structures.
 - (c) *Endoplasmic Reticulum (ER).* In mature oocytes the membranes of ER usually do not have ribosomes but are perforated by pores.
 - (d) *Cortical granules.* These are spherical bodies surrounded by a simple membrane and contain acid mucopolysaccharides. In mature oocytes, formation of cortical granules takes place.
 - (e) *Vitellogenesis.* Synthesis of yolk in the primary oocytes is called vitellogenesis. In fishes and amphibians, vitellogenesis takes place inside modified mitochondria. In other vertebrates, the yolk is not synthesized in the oocytes but is produced in the liver of the body of the female. It is then transported in a soluble form *via* blood to the follicle cells of the oocytes where it is finally deposited in the form of yolk granules or yolk platelets.

Menarche (Gr. *men*— month, *arche*— beginning)

Beginning of menstruation or first menstruation is called **menarche**. The beginning of menstruation varies. It usually occurs between 12 and 15 years.

MENSTRUAL CYCLE (Fig. 3.21 & 22)

Menstruation occurs in humans, apes and old world monkeys. Menstruation is bleeding from the uterus of adult females at intervals of one lunar month. In human females, the menstruation is repeated at an average interval of about 28/29 days and the cycle of events starting from one menstruation till the next one is called the **menstrual cycle**. One ovum is released (ovulation) during the middle of each menstrual cycle. As stated above menstrual cycle generally starts between 12 and 15 years and continues until about 45–50 years. It is regulated by certain hormones, some of which are secreted by the pituitary gland. The pituitary gland is stimulated by releasing factors produced in the hypothalamus. The hormones produced by the pituitary gland influence the ovaries. The hormones secreted by the ovaries affect the walls of the uterus.

The menstrual cycle consists of four phases : menstrual phase, proliferative phase, ovulatory phase and secretory phase.

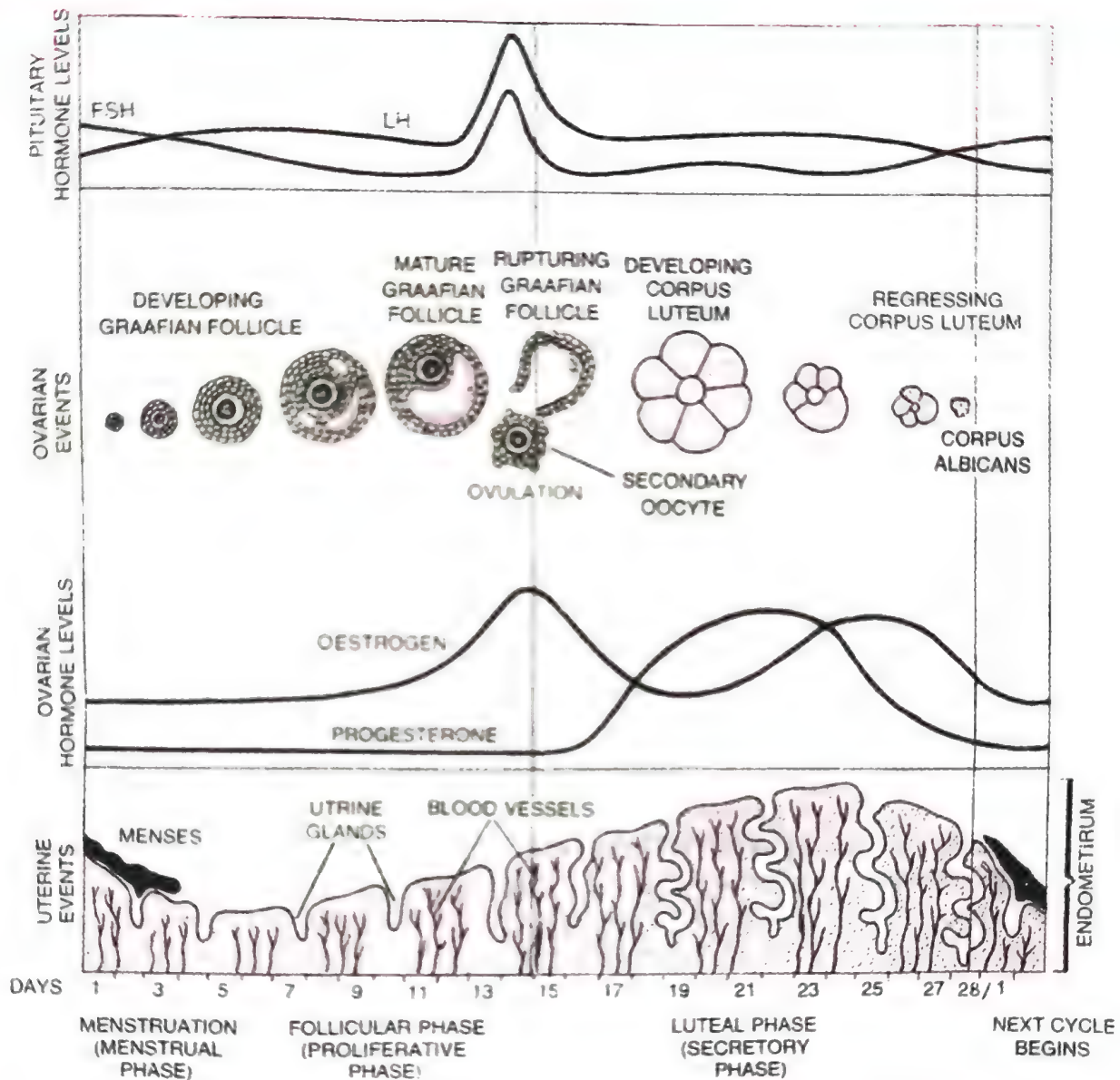


Fig. 3.21. Diagram showing various events during a menstrual cycle.

1. **Menstrual Phase (Bleeding phase or menses).** In a 28 day menstrual cycle, the menses takes place on cycle days 3–5. The production of LH from the anterior lobe of the pituitary gland is considerably reduced. The withdrawal of this hormone causes degeneration of the corpus luteum and, therefore, progesterone production is reduced. Production of oestrogens is also reduced in this phase. The endometrium of the uterus breaks down and menstruation begins. The cells of endometrium secretions, blood and the unfertilized ovum constitute the menstrual flow.

2. **Follicular Phase (Proliferative Phase).** This phase usually includes cycle days 6–13 or 14 in a 28 day cycle. The follicle stimulating hormone (FSH) secreted by the anterior lobe of the pituitary gland stimulates the ovarian follicle to secrete oestrogens.

Oestrogens stimulate the proliferation of the endometrium of the uterine wall. The endometrium becomes thicker by rapid cell multiplication and this is accompanied by an increase of uterine glands and blood vessels.

3. Ovulatory Phase. Both LH and FSH attain a peak level in the middle of cycle (about 14th day). Rapid secretion of LH induces rupturing of Graafian follicle and thereby the release of ovum (in human beings secondary oocyte is released). This is called **ovulation**. In fact LH causes ovulation.

4. Luteal Phase (Secretory Phase). This phase usually includes cycle days 15 to 28 in a 28 day cycle. The **luteinising hormone** (LH) is secreted by the anterior lobe of the pituitary gland. LH causes ovulation.

The remaining cells of the ovarian follicles are stimulated by the LH to develop **corpus luteum**. The corpus luteum secretes large amount of **progesterone**. Progesterone stimulates the uterine glands to produce increased amount of watery mucus. During the secretory phase, there is also similar increase in the secretion of watery mucus by the vaginal glands and by the glands of the Fallopian tubes. Progesterone is also essential for maintenance of the endothelium. Such an endothelium is necessary for implantation of the fertilized ovum and other events of pregnancy. In the absence of fertilization, the corpus luteum degenerates. This causes disintegration of the endothelium leading to menstruation marking a new cycle. Thus increases production of progesterone causes secretory phase.

Thus after the secretory phase, the menstrual phase begins. Menstruation is often described as "weeping of uterus for lost ovum".

Hormonal Control of Menstrual Cycle. Gonadotropin releasing hormone (GnRH) also called Gonadotropin releasing Factor (GnRF), is secreted by the hypothalamus of the brain, which stimulates the release of follicle stimulating hormone (FSH) and luteinizing hormone (LH). FSH stimulates the ovarian follicles to produce oestrogens during proliferative phase. LH stimulates the corpus luteum of the ovary to secrete progesterone.

- (1) Menstrual phase is caused by the reduction of progesterone and oestrogens.
- (2) Proliferative phase is caused by the increased production of oestrogens.
- (3) LH causes ovulation.
- (4) Secretory phase is caused by increased production of progesterone.

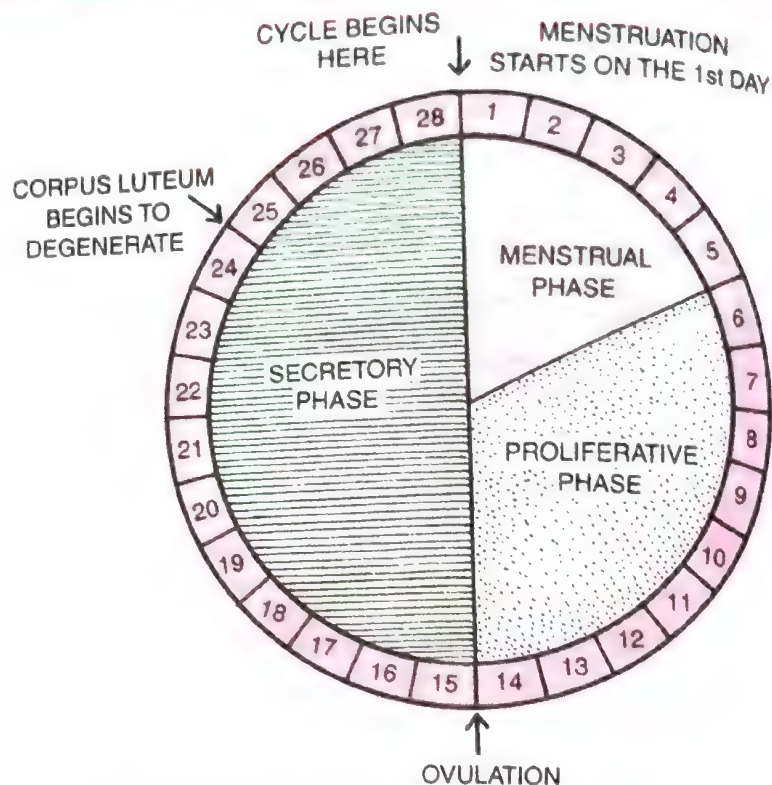


Fig. 3.22. Schematic representation of menstrual cycle.

Simplified Menstrual Cycle (28 day Cycle)

Phases	Days	Events
Menstrual Phase	1-5	Endometrium breaks down, menstruation begins. The cells of endometrium, secretions, blood and the unfertilized ovum constitute the menstrual flow. Progesterone production is reduced. In fact menstrual flow is associated with withdrawal of progesterone.
Follicular phase (Proliferative Phase)	6-13	Endometrium rebuilds, FSH secretion and oestrogen's secretion increase.
Ovulatory Phase	About 14th Day	Both LH and FSH attain a peak level. Concentration of oestrogen in the blood is also high and reaches its peak. Ovulation occurs.
Luteal Phase (Secretary Phase)	15-28	Corpus luteum secretes progesterone. Endometrium thickens and uterine glands become secretory.

Differences between Proliferative phase and Secretary Phase

Proliferative Phase (Follicular Phase)	Secretary Phase (Luteal Phase)
<ol style="list-style-type: none"> 1. It extends for about 10-12 days usually from day 6th to 13 in a 28 day cycle 2. Primary follicle changes into Graafian follicle. 3. Oestrogens are secreted. 4. Endometrium is about 2-3 mm thick. The uterine glands do not secrete watery secretion. 	<ol style="list-style-type: none"> 1. It extends for about 13-14 days after ovulation (usually from days 15 to 28 in a 28 day cycle). 2. Empty Graafian follicle changes into corpus luteum. 3. Progesterone is secreted. 4. Endometrium is about 5 mm. The uterine glands secrete watery secretion.

MENOPAUSE (Gr. *men* = month, *pausis* = cessation)

Definition. It is a phase in woman's life when ovulation and menstruation stop.

Period. It occurs between 45 to 55 years of age. Some women have irregular cycles for months or years prior to menopause. Others simply stop menstruating abruptly.

Cause. One theory is that menopause is a result of changes in pituitary gland and the nearby hypothalamus. Another theory suggests that menopause may begin when no follicles are left in the ovaries. In fact decline in oestrogen and progesterone level leads to menopause.

Symptoms. The uterus and the vagina gradually become atrophic (decreased work). Women may suffer temporarily depression, hot flashes, and other physiological and psychological problems in menopause. Most of these symptoms can be relieved by taking hormones prescribed by a physician. But this replacement of hormones is not encouraged due to some side effects.

FERTILIZATION

Definition. The fusion of a haploid male gamete (sperm) and a haploid female gamete (ovum) to form a diploid zygote is called fertilization.

The idea of fertilization was known to Leeuwenhoek in 1683.

Site of Fertilization. In human beings, fertilization takes place mostly in the ampullary region of the oviduct (Fallopian tube).

Arrival of Sperms. Male discharges semen into the female's vagina close to the cervix during coitus (copulation). This is called **insemination**. A single ejaculation of semen may contain 300 million sperms.

Movement of Sperms. From the vagina the sperms travel up the uterus but only a few thousand find their way into the openings of the fallopian tubes. Primarily, contractions of the uterus and fallopian tubes assist in sperm movement but later on they move by their own motility. Sperms swim in the fluid medium at the rate of 1.5 to 3 mm per minute to reach the site. The leucocytes of the vaginal epithelium engulf millions of sperms.

Arrival of Secondary Oocyte. In human beings, the secondary oocyte is released from the mature Graafian follicle of an ovary (ovulation). The oocyte is received by the nearby Fallopian funnel and sent into the Fallopian tube by movements of fimbriae and their cilia. The secondary oocyte can be fertilized only within 24 hours after its release from the ovary. The secondary oocyte is surrounded by numerous sperms but only one sperm succeeds in fertilizing the oocyte. Since the second meiotic division is in progress, so the sperm enters the secondary oocyte. Second meiotic division is completed by the entry of the sperm into the secondary oocyte. After this secondary oocyte is called ovum (egg).

Capacitation of Sperms. The sperms in the female's genital tract are made capable of fertilizing the egg by secretions of the female genital tract. These secretions of the female genital tract remove coating substances deposited on the surface of the sperms particularly those on the acrosome. Thus, the receptor sites on the acrosome are exposed and sperm becomes active to penetrate the egg. This phenomenon of sperm activation in mammals is known as **capacitation**. It takes about 5 to 6 hours for capacitation.

The secretions of seminal vesicles, prostate gland and bulbourethral glands (Cowper's glands) in the semen contain nutrients which activate the sperms. The secretions of these glands also neutralise the acidity in the vagina. Alkaline medium makes the sperms more active.

Physical and Chemical Events of Fertilization. These events include the following processes.

(i) **Acrosomal Reaction.** After ovulation, the secondary oocyte reaches the Fallopian tube (oviduct). The capacitated sperms undergo **acrosomal reaction** and release various chemicals contained in the acrosome. These chemicals are collectively called **sperm lysins**. Important sperm lysins are (i) **hyaluronidase** that acts on the ground substances of follicle cells, (ii) **corona penetrating enzyme** that dissolves corona radiata and (iii) **zona lysine** or **acrosin** that helps to digest the zona pellucida.

Optimum pH, Ca^{++} , Mg^{++} ions concentration and temperature are essential for acrosomal reaction. Ca^{++} plays major role in acrosomal reaction. In the absence of Ca^{++} , fertilization does not occur.

Due to acrosomal reaction, plasma membrane of the sperm fuses with the plasma membrane of the secondary oocyte so that the sperm contents enter the oocyte. Binding of the sperm to the secondary oocyte induces depolarization of the oocyte plasma membrane. Depolarization prevents **polyspermy** (entry of more than one sperm into the oocyte). It ensures **monospermy** (entry of one sperm into the oocyte).

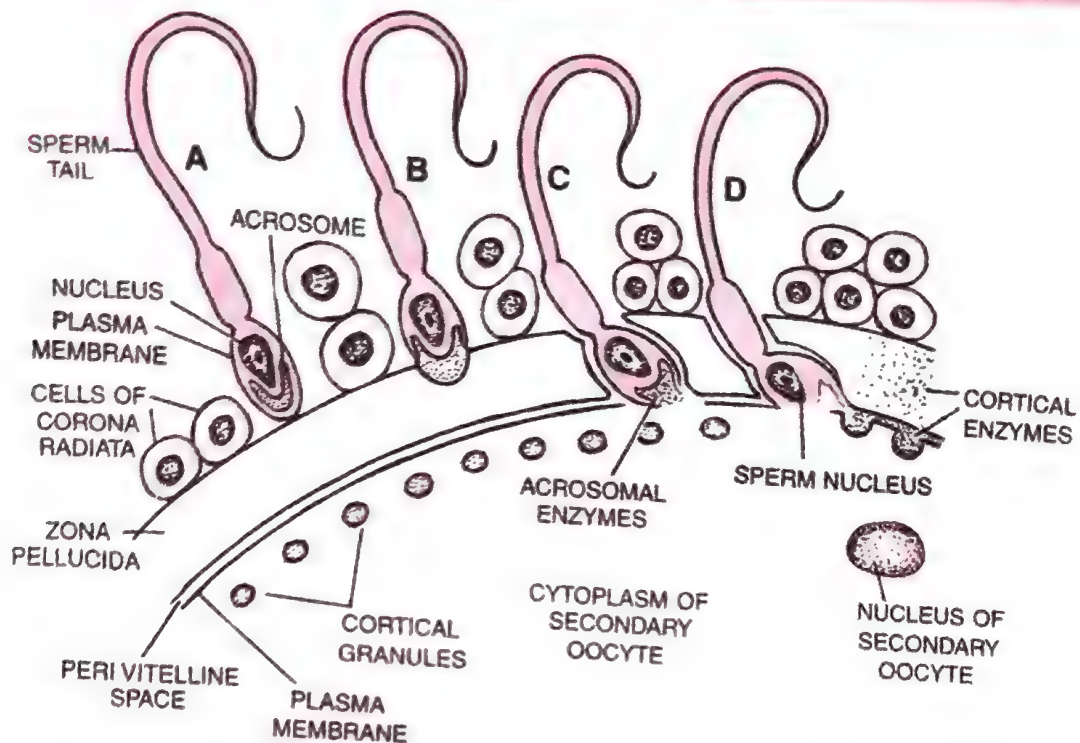


Fig. 3.23. Stages of sperm entry into the ovum during fertilization.

(ii) **Cortical Reaction.** Just after the fusion of sperm and plasma membranes of oocyte, the secondary oocyte shows a **cortical reaction**. The cortical granules are present beneath the plasma membrane of the secondary oocyte. These granules fuse with the plasma membrane of the oocyte and release their contents including **cortical enzymes** between the plasma membrane and the zona pellucida. These enzymes harden the zona pellucida which also prevents entry of additional sperms (polyspermy).

(iii) **Sperm Entry.** At the point of contact with the sperms, the secondary oocyte forms a projection termed the **cone of reception** or **fertilization cone** which receives the sperm. The proximal centriole of the sperm divides and forms two centrioles to generate the mitotic spindle formation for cell division. The mammalian secondary oocyte (egg) does not have centrioles of its own.

(iv) **Karyogamy (Amphimixis).** Sperm entry stimulates the secondary oocyte to complete the suspended second meiotic division. This produces a haploid mature ovum and a second polar body. The head of the sperm which contains the nucleus separates from the middle piece and the tail and becomes the **male pronucleus**. The second polar body and the sperm tail degenerate. The nucleus of the ovum is now called, the **female pronucleus**. The male and female pronuclei move towards each other. Their nuclear membranes disintegrate. Mixing up of the chromosomes of a sperm and an ovum is known as **karyogamy** or **amphimixis**. The fertilized ovum (egg) is now called **zygote**. The zygote is diploid unicellular cell that has 46 chromosomes in humans. The mother is now said to be **pregnant**.

(v) **Activation of Egg.** Sperm entry stimulates metabolism in the zygote. As a result, the rates of cellular respiration and protein synthesis increase greatly. Besides activating the egg another role of sperm is to carry DNA to egg.

Significance of Fertilization. Fertilization has the following significances. (i) It restores

the diploid number of chromosomes, characteristic of the species viz., 46 in human being. (ii) Fertilization initiates cleavage. (iii) It introduces the centrioles which are lacking in the mature egg. (iv) Fertilization results in determination of sex in the embryo. (v) It combines the characters of two parents. This introduces variations. (vi) Fertilization membrane developed after the entry of the sperm prevents the entry of other sperms into the ovum.

FERTILIZIN-ANTIFERTILIZIN INTERACTION

F. R. Lillie proposed **fertilization theory** in 1914 which is based on Sea Urchin (an Echinoderm). According to this theory egg (ovum) secretes a chemical named **fertilizin** (composed of glycoprotein = monosaccharides + amino acids) and sperm has on its surface a protein substance called **antifertilizin** (composed of acidic amino acids). The fertilizin of an egg interacts with the antifertilizin of a sperm of the same species. This interaction makes the sperms stick to the egg surface. The adhesion of sperm to the egg of the same species through chemical recognition is known as **agglutination**.

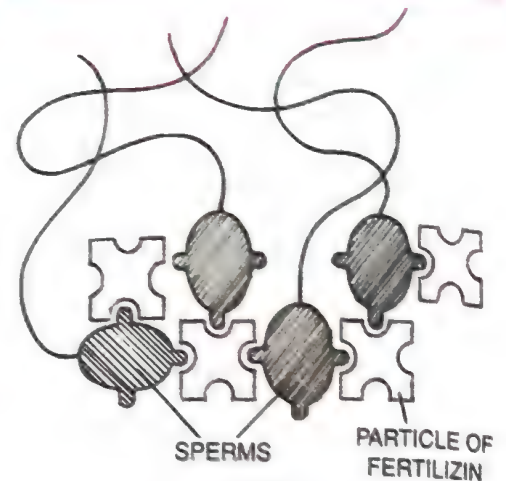
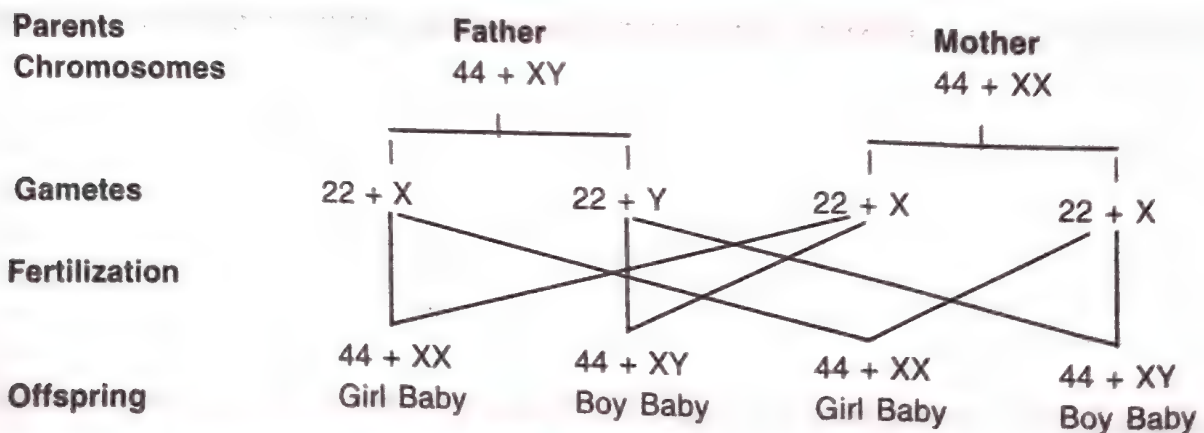


Fig. 3.24. Fertilizin-Antifertilizin reaction in sea urchin.

SEX OF THE BABY

The sex chromosome pattern in the human females is XX and that of male is XY. Therefore, all the haploid female gametes (ova) have the sex chromosome X, however, the haploid male gametes have either X or Y. Thus 50% of sperms carry the X-chromosome while the other 50% carry the Y-chromosome. After fusion of the male and female gametes, the zygote carries either XX or XY depending upon whether the sperm carrying X or Y fertilizes the ovum. The zygote carrying XX would be a female baby and XY would be a male baby. That is why it is correct to say that the sex of the baby is determined by the father as shown below.



EMBRYONIC DEVELOPMENT

Cleavage

Definition. Cleavage is a series of rapid mitotic divisions of the zygote which convert the single celled zygote into a multicellular structure called blastula (blastocyst).

Process. About thirty hours after fertilization, the newly formed zygote divides into two cells, the **blastomeres**, in the upper portion of the Fallopian tube. This is the first cleavage. The next division occurs within forty hours after fertilization. The third division occurs about three days after fertilization. During these early cleavages, the young embryo is slowly moving down the Fallopian tube towards the uterus.

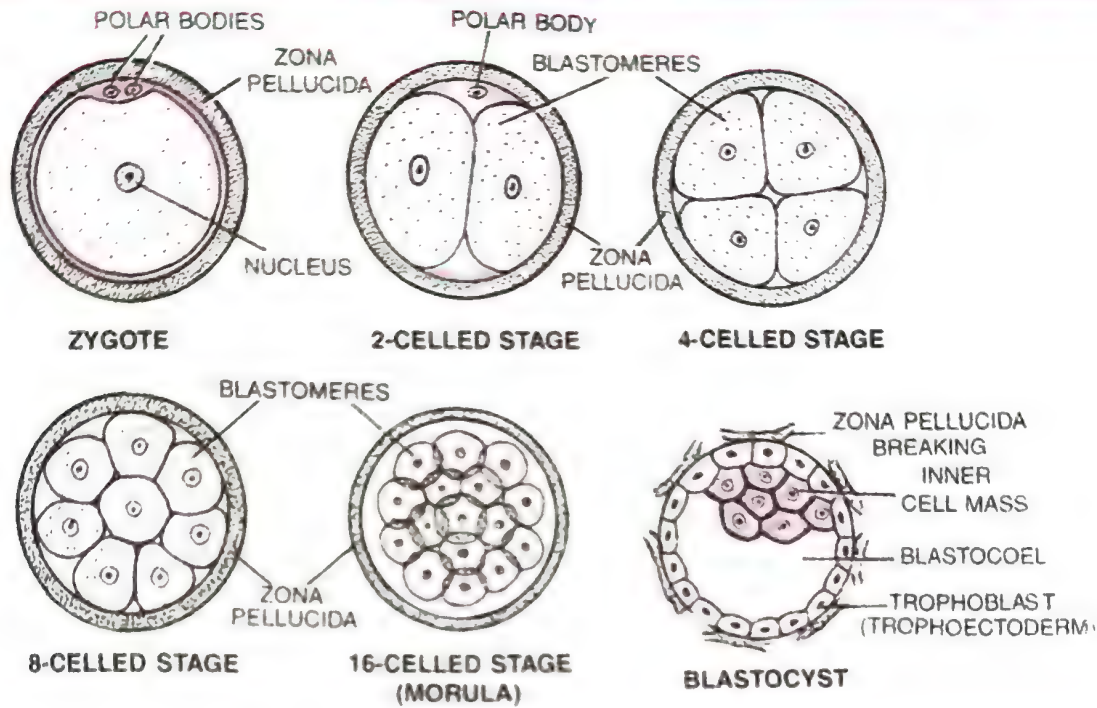


Fig. 3.25. Early stages of embryonic development.

At the end of fourth day, the embryo reaches the uterus. It has 8–16 blastomeres and this solid mass of cells is known as **morula** (little mulberry) as it looks like a mulberry. When the blastomeres divide completely the cleavage is called **holoblastic**.

Significance of Cleavage. Cleavage brings about (i) the distribution of the cytoplasm of the zygote, amongst the blastomeres, (ii) increased mobility of the protoplasm, which facilitates morphogenetic movements necessary for cell differentiation, germ layer formation and the formation of tissue and organs, (iii) the restoration of the cell size and the nucleo-cytoplasmic ratio characteristic of the species. (iv) Unicellular zygote is converted into multicellular embryo.

Differences between Cleavage and Typical Mitosis

<i>Cleavage</i>	<i>Typical Mitosis</i>
1. It occurs in zygote or parthenogenetic egg.	1. It occurs in most of body cells.
2. Interphase is short.	2. Interphase is of long duration.
3. Growth does not occur.	3. Growth occurs during interphase.
4. Oxygen consumption is high as it is very rapid process.	4. Oxygen consumption is low as it is slow process.
5. Size of blastomeres decreases.	5. Size of daughter cells remains same after growth.
6. DNA synthesis is faster.	6. DNA synthesis is slower.
7. Nuclear-cytoplasmic ratio increases.	7. Nuclear-cytoplasm ratio remains same.

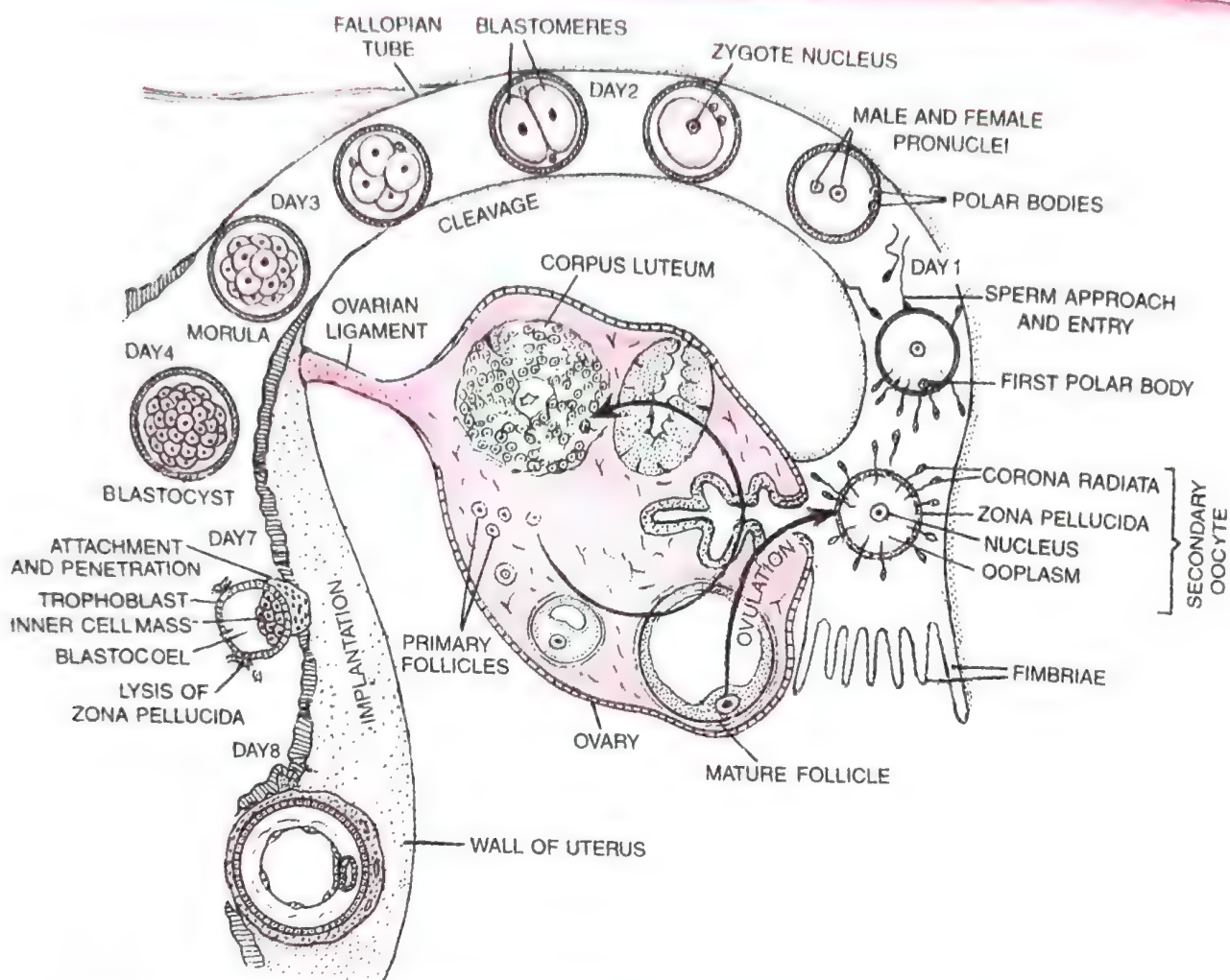


Fig. 3.26. Diagram showing ovulation, fertilisation, cleavage and implantation of blastocyst.

Blastocyst Formation. At the next stage of development, which produces an embryo with about sixty four cells, a cavity is formed within the cell mass. This cavity is called **blastocyst cavity** (Blastocoel) and the embryo is termed the **blastocyst** which is composed of an outer envelope of cells, the **trophoblast** or **trophoectoderm** and **inner cell mass** (= embryoblast). The side of the blastocyst to which the inner cell mass is attached is called the **embryonic** or **animal pole** while the opposite side is the **abembryonic pole**. The trophoblast encircles the blastocoel and the inner cell mass. The inner cell mass is the *precursor of the embryo*. It means the inner cell mass gives rise to the embryo. The cells of trophoblast (Gr. *trophe*— nourishment) help to provide nutrition to the embryo. The cells of the trophoblast later form the extra embryonic membranes namely chorion and amnion and part of the placenta. The cells of the trophoblast which are in contact with the inner cell mass are called **cells of Rauber**.

Differences between Morula and Blastula

Morula	Blastula (Blastocyst)
1. It is a solid ball like structure which looks like a little mulberry.	1. It is a hollow structure with a blastocoel/blastocyst cavity in the centre.
2. It is formed of similar cells.	2. It is formed of outer nutritive layer, trophoblast, and an inner cell mass.
3. Zona pellucida is intact.	3. Zona pellucida starts disintegrating.

Implantation. Implantation is the attachment of the blastocyst to the uterine wall. It occurs after 7 days of fertilization. About 8 days after fertilization, the trophoblast develops into two layers in the region of contact between the blastocyst and endometrium. These layers are (a) **syncytiotrophoblast** that contains non-distinct cell boundaries and (b) **cytotrophoblast** between the inner cell mass and syncytiotrophoblast that is composed of distinct cells. The portion of the blastocyst where the inner cell mass is located lies against the endometrium of the uterus. The blastocyst sinks into a pit formed in the endometrium and gets completely buried in the endometrium. The embedded blastocyst forms villi to get nourishment.

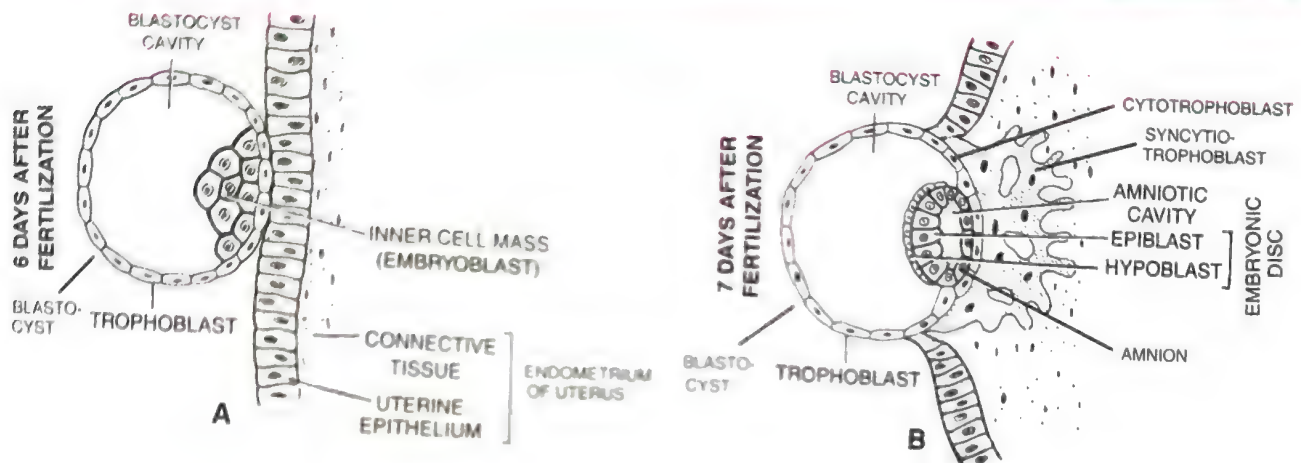


Fig. 3.27. Implantation of blastocyst.

The cells of the inner cell mass differentiate into two layers. (a) a layer of small, cuboidal cells known as the **hypoblast layer**; and (b) a layer of high columnar cells, the **epiblast layer**. Both the hypoblast and epiblast form a flat disc called the **embryonic disc**.

Role of Zona Pellucida. Occasionally the blastocyst implants close to the internal os. The function of the zona pellucida is to prevent the implantation of the blastocyst at an abnormal site. It does not expose the sticky and phagocytic cells of the trophoblast till the blastocyst reaches the proper implantation site. As the blastocyst is formed, zona pellucida becomes thinner and finally disappears.

Role of Human Chorionic Gonadotropin (hCG). The trophoblastic cells secrete human chorionic gonadotropin hormone which has properties similar to those of luteinizing hormone (LH) of the pituitary gland. It takes over the job of pituitary LH during pregnancy. The hCG maintains the corpus luteum and stimulates it to secrete progesterone. The latter maintains the endometrium of the uterus and causes it to grow throughout pregnancy. This also prevents menstruation. Progesterone also causes increased secretion of mucus in the cervix of the uterus that forms a protective plug during pregnancy.

Decidua (*L. deciduus* = falling off)

If implantation occurs, a portion of the endometrium of the uterus becomes modified and is called the **decidua**. The decidua is shed when the foetus is delivered. There are three kinds of decidua.

(i) **Decidua basalis.** It is the portion of the endometrium between the chorion and the myometrium of the uterus. The decidua basalis becomes the maternal part of the placenta.

(ii) **Decidua capsularis.** It is the portion of the endometrium between the embryo and uterine cavity.

(iii) **Decidua parietalis.** It is the portion of the modified endometrium that lines the entire pregnant uterus, except for the area where the placenta is forming.

The implantation leads to the pregnancy. If hCG is present in a woman's urine it indicates her pregnancy.

Embryo and Foetus

Embryo is an organism in the early stages of development. In human beings, the developing organism from conception until approximately the end of the eight week (second month) is called embryo.

Foetus is the unborn young one of a viviparous animal after it has taken form in the uterus. In human beings, an embryo is called foetus from the end of the eight week till birth.

Gastrulation

Definition. Transformation of the blastocyst into the gastrula with primary germ layers by rearrangement of the cells is called **gastrulation**. (Gr. *gaster*—belly). Gastrulation involves cell movements that help to attain new shape and morphology of the embryo. These cell movements are called **morphogenetic movements**. In all the triploblastic animals, three germ layers namely ectoderm, mesoderm and endoderm, are formed by the morphogenetic movements.

Process. In human, the germ layers are formed so quickly that it is difficult to determine the exact sequence of events.

Formation of Embryonic Disc.

We have seen that early blastocyst consists of inner cell mass and trophoblast. The inner cell mass contains cells called **stem cells** which have the potency to give rise to all tissues and organs. The cells of the inner cell mass differentiate into two layers around 8 days after fertilization, a hypoblast and epiblast. The **hypoblast (primitive endoderm)** is a layer of smaller cuboidal cells and **epiblast (primitive ectoderm)** is a layer of larger columnar cells. The cells of the hypoblast and epiblast together form a two layered **embryonic disc**.

Formation of Amniotic Cavity.

A space appears between epiblast and trophoblast, called **amniotic cavity** filled with **amniotic fluid**. The roof of this cavity is formed by **amniogenic cells** derived from the trophoblast, while its floor is formed by the epiblast.

Formation of Extra-embryonic Coelom. The cells of the trophoblast give rise to the mass of cells called the **extra-embryonic mesoderm**. This mesoderm is called extraembryo itself. The extraembryonic mesoderm is differentiated into outer **somatopleuric extra-embryonic mesoderm** and inner **splanchnopleuric extra-embryonic mesoderm**. Both these layers enclose the **extra-embryonic coelom**.

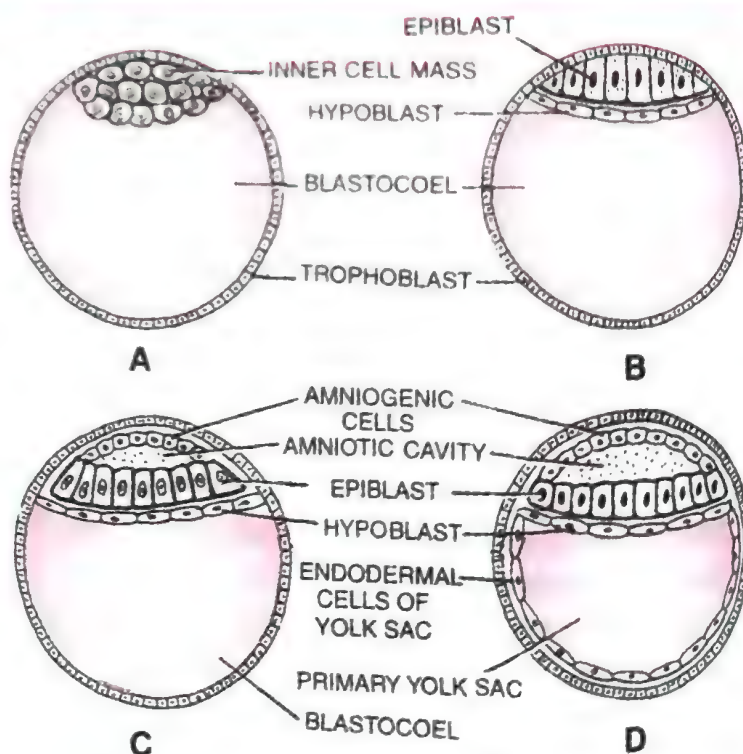


Fig. 3.28. Diagrams showing formation of epiblast, hypoblast, amniotic cavity and yolk sac.

Formation of Chorion and Amnion. At this stage, two very important embryonic membranes, the chorion and amnion, are formed. The **chorion** is formed by the somatopleuric extra-embryonic mesoderm inside and the trophoblast outside. The **amnion** is formed by the amniogenic cells inside and somatopleuric extraembryonic mesoderm outside. As mentioned earlier the amniogenic cells are derived from the trophoblast. Later on chorion becomes the main embryonic part of the placenta. The chorion also produces **human chorionic gonadotropin (hCG)** an important hormone of pregnancy. Amnion surrounds the embryo creating the amniotic cavity that is filled with amniotic fluid. The amniotic fluid serves as a shock absorber for the foetus, regulates foetal body temperature and prevents desiccation.

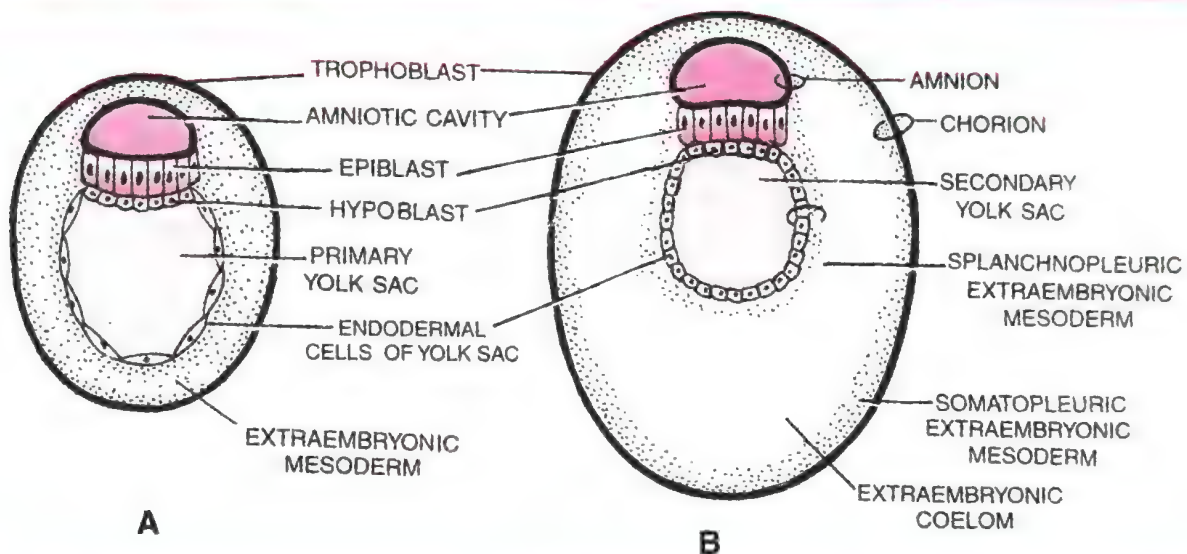


Fig. 3.29. Diagrams showing formation of extra-embryonic mesoderm and extra-embryonic coelom.

Formation of Yolk Sac. Flattened cells arising from the hypoblast spread and line inside the blastocoel. These are endodermal cells lining the **primary yolk sac**. With the appearance of the extraembryonic mesoderm and later of the extraembryonic coelom, the yolk sac (embryonic membrane) becomes much smaller than before and is now called the **secondary yolk sac**. This change in size is due to change in the nature of the lining cells. These cells are no longer flattened but become cubical. The secondary yolk sac consists of outer splanchnopleuric extra embryonic mesoderm and inner endodermal cells.

The yolk sac is a source of blood cells. It also functions as a shock absorber and helps prevent desiccation of the embryo.

Formation of Primitive Streak. Gastrulation involves the rearrangement and migration of cells from the epiblast. A **primitive streak** which is a faint groove on the dorsal surface of the epiblast is formed. It elongates from the posterior to the entire part of the embryo. The primitive streak clearly establishes the head and the tail ends of the embryo as well as its right and left sides.

Formation of Germ Layers/Embryonic Layers. After the formation of the primitive streak, cells of the epiblast move inward below the primitive streak and detach from the epiblast. This inverting movement is called **invagination**. (i) Once the cells have invaginated, some of them separate from the hypoblast forming the **endoderm**. Endoderm develops first during embryonic development. (ii) Other cells remain between the epiblast and newly formed endoderm forms the **mesoderm**. (iii) Cells remaining in the epiblast form **ectoderm**.

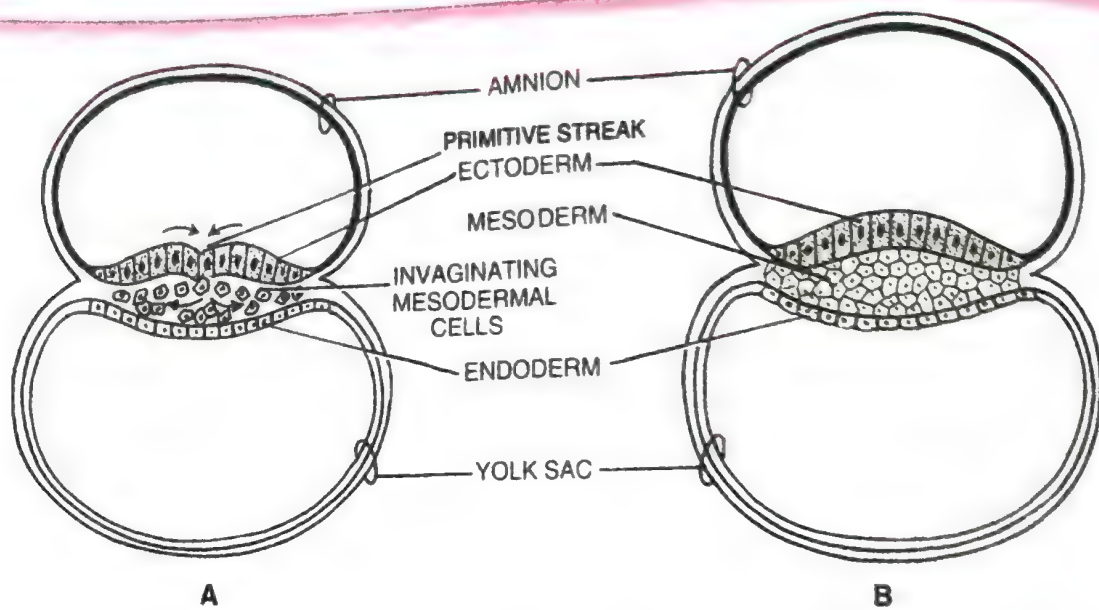


Fig. 3.30. Formation of primitive streak and three germ layers.

Thus three germ layers, namely endoderm, mesoderm and ectoderm are formed which give rise to all the tissues and organs of the body.

Differences between Trophoectoderm and Ectoderm	
<i>Trophoectoderm (Trophoblast)</i>	<i>Ectoderm</i>
<ol style="list-style-type: none"> 1. It is the outermost layer of cells of a blastocyst. 2. It forms the foetal part of placenta and does not form any part of the embryo proper. 	<ol style="list-style-type: none"> 1. It is the outermost layer of cells of a gastrula. 2. It forms parts like brain, spinal cord, etc. in the embryo proper.

Differences between Blastulation and Gastrulation	
<i>Blastulation</i>	<i>Gastrulation</i>
<ol style="list-style-type: none"> 1. There are rapid mitotic divisions of zygote. 2. Cells do not move. 3. A single layered hollow blastula (blastocyst) is formed. 	<ol style="list-style-type: none"> 1. There are slow mitotic divisions in the blastula (blastocyst). 2. Cell masses show morphogenetic movements. 3. A 3-layered gastrula is formed.

Fate of Three Germ Layers

Each germ layer gives rise to the specific tissues, organs and organ-systems. The germ layers have the similar fate in various animals.

Derivatives of Ectoderm. (1) Epidermis of skin, hair, arrector pili muscles, nails, sudoriferous (sweat) and sebaceous (oil) glands and chromatophores (pigment cells) of skin. (2) Enamel of teeth, salivary glands, mucous membrane of lips, cheeks, gums, part of the floor of the mouth and part of palate, nasal cavities and paranasal sinuses. Lower part of anal canal. (3) Nervous system including all neurons, neuroglia (except microglia), and Schwann

cells. Pia mater and arachnoid mater. (4) Conjunctiva, cornea, lens of eye, muscles of iris, vitreous humour, retina, lacrimal gland. (5) External ear, outer layer of tympanic membrane, membranous labyrinth (internal ear). (6) Pituitary gland, pineal gland and medulla of adrenal glands. (7) Mammary glands, outer surface of labia minora and whole of labia majora. (8) Terminal part of male urethra.

Derivatives of Mesoderm. (1) Muscles except iris muscles. (2) Connective tissues including loose areolar tissue, ligaments, tendons and the dermis of skin. (3) Specialised connective tissues like adipose tissue, reticular tissue, cartilage and bone. (4) Dentin of teeth. (5) Heart, all blood vessels, lymphatics, blood cells, spleen. (6) Kidneys, ureters, trigone of urinary bladder. (7) Coelomic epithelium (mesothelium of pleural, pericardial and peritoneal cavities). (8) Duramater, microglia. (9) Sclera, choroid, ciliary body and iris. (10) Basis of tympanic membrane. (11) Cortex of adrenal glands. (12) Mesenteries (13) Notochord. (14) Reproductive system except prostate.

Derivatives of Endoderm. (1) Epithelium of mouth, part of palate, tongue, tonsils, pharynx, oesophagus, stomach, small and large intestines including upper part of anal canal (not lower part of anal canal). (2) Epithelium of Eustachian tube, middle ear, inner layer of tympanic membrane. (3) Epithelium of larynx, trachea, bronchi and lungs. (4) Epithelium of gall bladder, liver, pancreas including islets of Langerhans, gastric and intestinal glands. (5) Epithelium of urinary bladder except trigone. (6) Epithelium of lower part of vagina, vestibule and inner surface of labia minora. (7) Epithelium of prostate (except inner glandular zone), bulbourethral glands, greater vestibular and lesser vestibular glands. (8) Epithelium of thyroid, parathyroid and thymus glands.

Extra-Embryonic or Foetal Membranes (Fig. 3.31)

The growing embryo/foetus develops four membranes called the **extra embryonic** or **foetal membranes**. These include chorion, amnion, allantois and yolk sac.

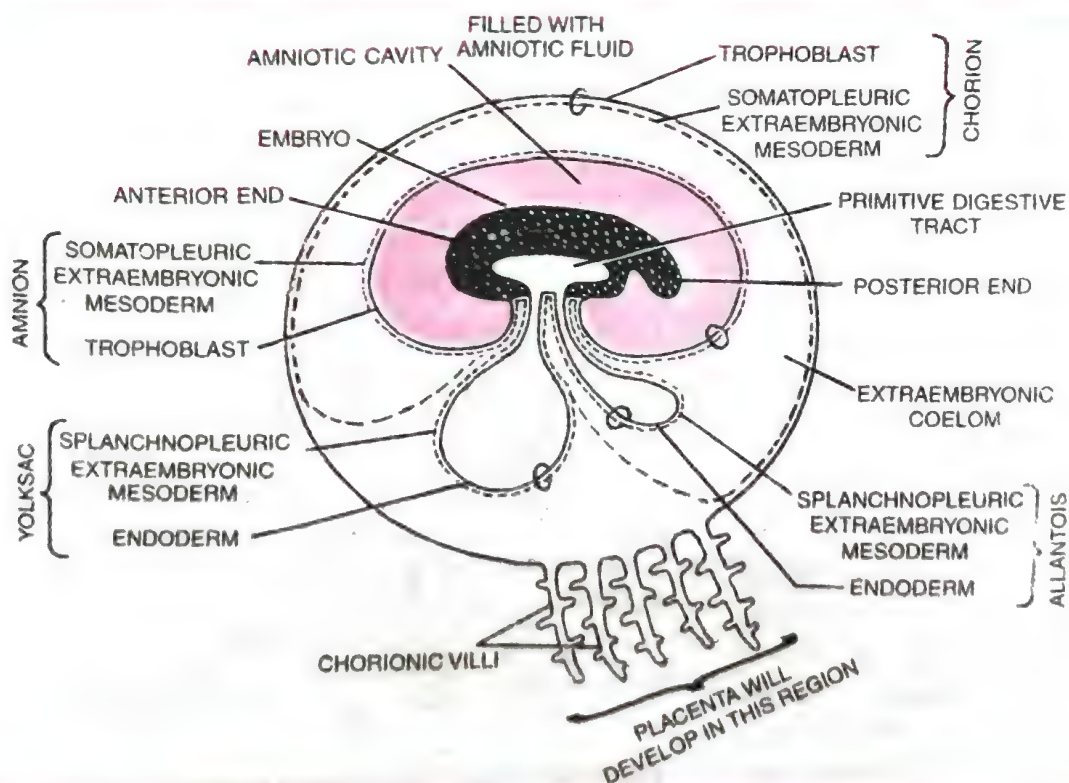


Fig. 3.31. Diagram showing foetal membranes (schematic).

(i) **Chorion.** It is made up of trophoblast outside and somatopleuric extraembryonic mesoderm inside. It completely surrounds the embryo and protects it. It also takes part in the formation of placenta.

(ii) **Amnion.** It is composed of trophoblast inside and somatopleuric extraembryonic mesoderm outside. The space between the embryo and the amnion is called the **amniotic cavity** which is filled with a clear, watery fluid secreted by both the embryo and the membrane. The amniotic fluid prevents desiccation of the embryo and acts as a protective cushion that absorbs shocks.

(iii) **Allantois.** The allantois is composed of endoderm inside and splanchnopleuric extraembryonic mesoderm outside. It is a sac-like structure which arises from the gut of the embryo near the yolk sac. In human the allantois is small and nonfunctional except for furnishing blood vessels to the placenta.

(iv) **Yolk sac.** The primary yolk sac consists of endoderm inside and splanchnopleuric extraembryonic mesoderm outside. The yolk sac is nonfunctional in human beings except that it functions as the site of early blood cell formation.

Pregnancy

Pregnancy is the time from conception to birth. In human beings it is approximately 9 months \pm 7 days. The duration of pregnancy in dogs, elephants and cats is 63, 624 and 63 days respectively. Placenta plays an important role in pregnancy.

Placenta

Placenta is the intimate connection between the foetus and uterine wall of the mother to exchange the materials. The outer surface of the chorion in humans develops a number of finger like projections, known as **chorionic villi**, which grow into the tissue of the uterus. These villi, penetrate the tissues of the uterine wall in which they are embedded, make up the organ known as the placenta by means of which the developing embryo obtains nutrients and oxygen and gets rid of carbon dioxide and metabolic wastes. Because the chorion takes part in the formation of placenta, the human placenta is called the **chorionic placenta**. It consists of foetal part, the chorion and a maternal part the decidua basalis. The foetal part of placenta grows to invade the uterine mucosa with its chorionic villi. The degree of intimacy is so strong that the blood vessels of the chorionic villi are bathed in the mother's blood. This is due to erosion of the uterine mucosa, including its epithelium,

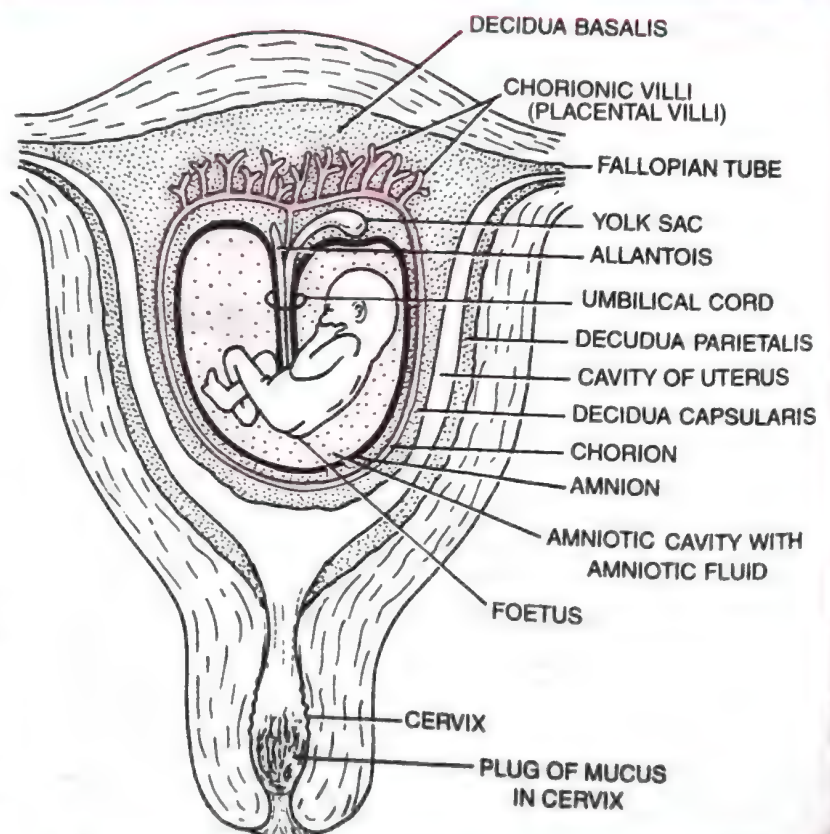


Fig. 3.32. Human foetus within the uterus showing placenta.

connective tissue and the endothelial lining. This type of placenta which is based on the intimacy between foetal and maternal parts of the placenta, is referred to as **haemochorial placenta**. The placenta is connected to embryo through an **umbilical cord** which helps in the transport of substances to and from the embryo. On the basis of the distribution of villi on chorion, human placenta is called **metadiscoidal placenta**.

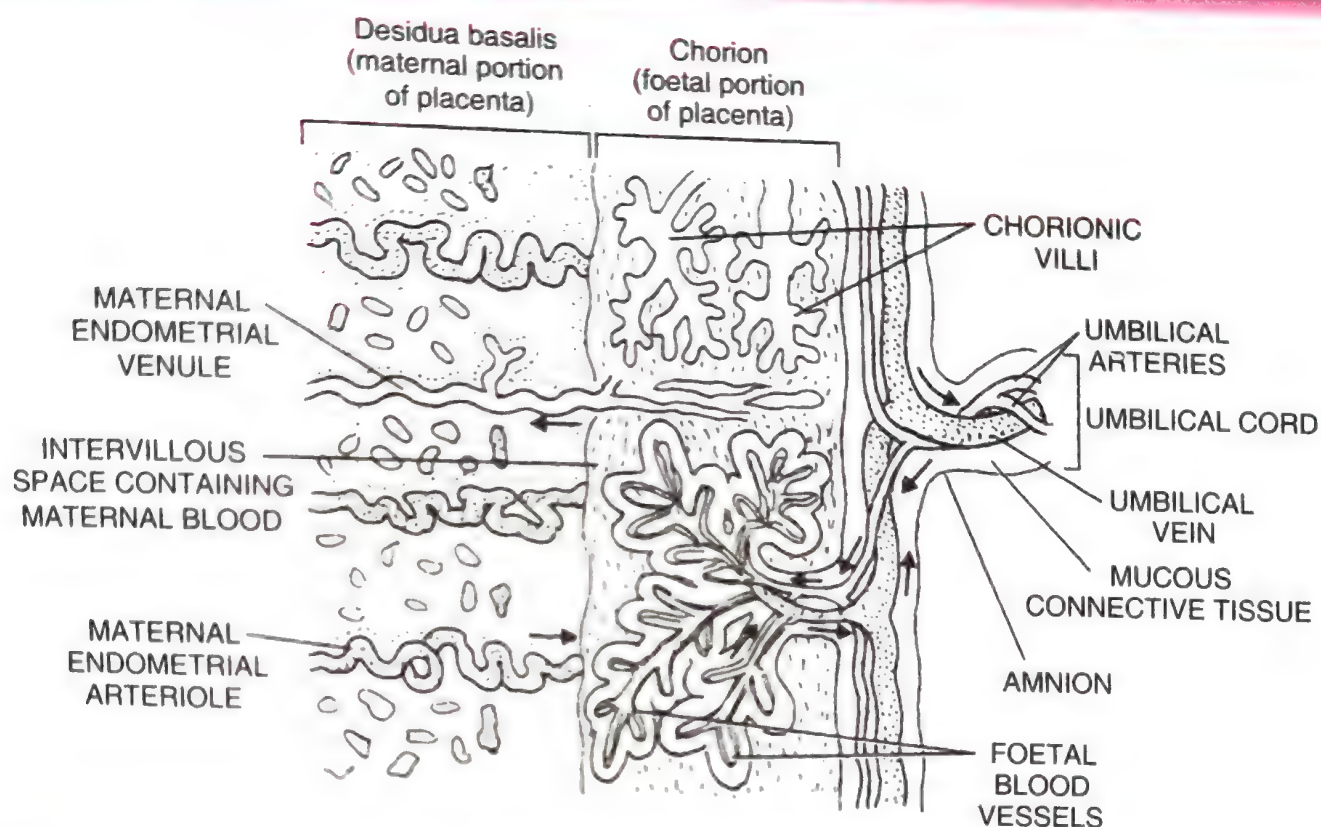


Fig. 3.33. Diagram showing structure of the placenta and umbilical cord.

The placenta performs the following functions. (i) **Nutrition.** All the nutritive elements from the maternal blood pass into the foetus through the placenta. (ii) **Respiration.** Oxygen passes from the maternal blood to the foetal blood through the placenta, and carbon dioxide passes in the reverse direction. (iii) **Excretion.** The foetal excretory products diffuse into the maternal blood through placenta and are excreted by the mother. (iv) **Storage.** Placenta stores glycogen, fat, etc. (v) **As a Barrier.** Placenta serves as an efficient barrier and allows those materials to pass into the foetal blood that are necessary. **Teratogens** are certain agents (viruses or chemicals) or drugs that cause abnormal development in developing embryo/foetus. The most well known synthetic teratogen drug is **thalidomide**. This drug causes multiple defects in the growing embryo. (vi) **Endocrine Function.** Placenta secretes some hormones such as **oestrogens**, **progesterone**, **human chorionic gonadotropin (hCG)**, **human chorionic somatomammotropin—hCS** (it was formerly known as **human placental lactogen—hPL**), **chorionic thyrotropin**, **chorionic corticotropin** and **relaxin**. The hCG stimulates and maintains the corpus luteum to secrete progesterone until the end of pregnancy. The hCS stimulates the growth of the mammary glands during pregnancy. Relaxin facilitates parturition (act of birth) by softening the connective tissue of the pubic symphysis.

In addition, the levels of hormones like oestrogens, progestogens, cortisol, prolactin, thyroxine, etc. are increased in the maternal blood during pregnancy. Increased production

of these hormones is necessary for supporting the foetal growth, metabolic changes in the mother and maintenance of pregnancy.

Important Developmental Changes in the Human Embryo

Time from Fertilization	Organs Formed
Week 1	Fertilisation cleavage starts about 24 hours after fertilization. Cleavage to form a blastocyst 4–5 days after fertilisation. More than 100 cells. Implantation 6–9 days after fertilisation.
Week 2	The three primary germ layers (ectoderm, endoderm and mesoderm) develop.
Week 3	Woman will not have a period. This may be the first sign that she is pregnant. Beginnings of the backbone. Neural tube develops, the beginning of the brain and spinal cord (first organs).
Week 4	Heart, blood vessels, blood and gut start forming. Umbilical cord developing
Week 5	Brain developing, 'Limb buds', small swellings which are the beginnings of the arms and legs. Heart is a large tube and starts to beat, pumping blood. This can be seen on an ultrasound scan.
Week 6	Eyes and ears start to form
Week 7	All major internal organs developing. Face forming. Eyes have some colour. Mouth and tongue develop. Beginnings of hands and feet.
By week 12	Foetus fully formed, with all organs, muscles, bones, toes and fingers. Sex organs well developed. Foetus is moving.
By Week 20	Hair beginning to grow, including eyebrows and eyelashes. Fingerprints developed. Fingernails and toenails growing. Firm hand grip. Between 16 and 20 weeks baby usually felt moving for first time.
Week 24	Eyelids open. Legal limit for abortion in most circumstances.
By week 26	Has a good chance of survival if born prematurely.
By week 28	Baby moving vigorously. Responds to touch and loud noises. Swallowing amniotic fluid and urinating.
By week 30	Usually lying head down ready for birth.
40 weeks (9 months \pm 7 days)	Birth

Parturition And Lactation

Parturition (L. *Parturio* = to be in labour)

Meaning. The duration of pregnancy in human beings is about 9 months \pm 7 days which is called **gestation period**. Infact, the gestation period is the time from conception to birth.

At the end of the pregnancy vigorous contraction of uterus causes delivery or expulsion of the foetus. This act of expelling the full term young one from the mother's uterus at the end of gestation period is called **parturition**.

Process. Process of parturition is induced by both nervous system and hormones secreted by the endocrine glands of the mother. The signals for child birth (parturition) originate from the fully matured foetus and placenta which induce mild uterine contractions called **foetal ejection reflex**. This causes quick release of **oxytocin** from the maternal posterior lobe of pituitary gland. The amount of oxytocin is increased just before and during "labour pains" (pains of child birth). Childbirth begins with a long series of involuntary contractions of the uterus experienced as labour pains. Oxytocin (birth hormone) promotes contraction of the uterine muscles. **Relaxin** increases the flexibility of the pubis symphysis and ligaments of the sacroiliac and sacrococcygeal joints and helps dilate the uterine cervix during labour pains. Both of these actions give relief to the body from the pain during delivery of the baby. The hormone most recently found to be produced by the placenta is **corticotropin-releasing hormone (CRH)**, which in nonpregnant women is secreted only by neuro-secretory cells in the hypothalamus. CRH is now thought to be part of the "clock" that establishes the timing of birth. Secretion of CRH by placenta increases enormously toward the end of pregnancy. Women who have higher levels of CRH earlier in pregnancy are more likely to deliver prematurely, whereas those who have low levels are more likely to deliver after their due date.

Stages. Labour pains can be divided into three stages :

(i) **Stage of dilation.** The time from the onset of labour pain to the complete dilation of the cervix is called the **stage of dilation**. This stage lasts 6–12 hours. During this stage, regular contractions of the uterus, usually rupturing of the amniotic sac and complete dilation of the cervix occur. The first result of labour pains is the opening of the cervix. The amniotic fluid (the "waters") starts flowing out through the vagina.

(ii) **Stage of expulsion.** The time from complete cervical dilation to delivery of the baby is the **stage of expulsion**. It lasts 10 minutes to several hours. The baby passes through the cervix and vagina and is 'delivered' or born.

(iii) **Placental Stage.** The time after the delivery until the placenta or "afterbirth" is expelled by powerful uterine contraction is the **placental stage**. These contractions also constrict blood vessels that were torn during delivery thereby reducing the possibility of haemorrhage.

In about 28–35 days, the uterus returns fully to its nonpregnant state by reduction in size and restoration of endometrium of the uterus.

Lactation.

Meaning. Production of milk in the mammary glands is called lactation.

Period. The female's mammary glands undergo differentiation during pregnancy and start producing milk towards the end of pregnancy and after the birth of the young one.

Role of Hormones. At puberty in females mammary glands begin to develop under the influence of oestrogen and progesterone. Secretion and storage of milk generally begins after birth of young one, usually within 24 hours under the influence of hormone **prolactin (PRL)** secreted by anterior lobe of the pituitary gland. However, the ejection of milk is stimulated by the hormone **oxytocin (OT)** released from the posterior lobe of the pituitary gland.

Colostrum. The first milk which comes from the mammary glands of the mother just after child birth, for 2 or 3 days is called the **colostrum**. This is yellowish fluid that contains

cells from the alveoli and rich in protein (lactalbumin and lactoprotein) but low in fat. Colostrum contains antibodies (IgA is the major immunoglobulin in it) that provide passive immunity to the new born infant.

Composition of Milk. Human milk consists of water and organic and inorganic substances. Its main constituents are fat (**fat droplets**), **casein** (milk protein), **lactose** (milk sugar), mineral salts (sodium, calcium, potassium, phosphorous, etc.) and vitamins. Milk is poor in iron content. Vitamin C is present in very small quantity in milk. The process of milk secretion is regulated by the nervous system. It is also influenced by the psychic state of the mother. The process of milk production is also influenced by hormones of the pituitary gland (already mentioned), the ovaries and other endocrine glands. A nursing woman secretes of 1 to 2 litres of milk per day.

Importance of Breast feeding. Breast feeding during initial stage of infant growth is recommended by doctors for the healthy baby. Milk contains an **inhibitory peptide**. If the mammary glands are not fully emptied, the peptide accumulates and inhibits milk production. Breast feeding is also a means of birth control, but it is not reliable.

Developmental Disorders

1. **Amnionitis** (*amnion* + Gr suffix – *itis* – inflammation). Inflammation of amnion, usually resulting from premature rupture of the amnion and often associated with neonatal infection.

2. **Abortion.** It is giving birth to an embryo or foetus prior to the stage of viability at about 20 weeks of gestation (foetus weighs less than 500 gm). It may occur from natural causes or induced.

3. **Teratogeny** (Gr. *terato* = monster—abnormally misshaped animal or plant or person or thing, suffix *gen* = producing). Production of malformed infant is called teratogeny. It is due to use of drugs or other agents such as tobacco and alcohol by pregnant mother. These teratogens cause abnormal development.

ADDITIONAL INFORMATION

- **Glands of Tyson** are modified sebaceous glands located in the prepuce and glans penis of human penis.

- In prostate cancer the testes are removed.
- **Castration.** Removal of the testes or ovaries.

- **Hysterectomy.** Removal of the uterus (womb).

- **Prostatectomy—** Removal of a portion of the prostate.

- **Egg Membranes.** On the basis of their origin, the egg membranes are classified into three types.

(i) **Primary Egg Membrane.** It is secreted by ovum (egg) itself. Examples : Vitelline

membrane and zona pellucida (eggs of mammal).

(ii) **Secondary Egg Membrane.** It is formed by the follicle cells surrounding ovum in the ovary during its period of growth. Example : Corona radiata (eggs of mammals) and chorion (eggs of insect).

(iii) **Tertiary Egg Membrane.** It is secreted by the oviduct or uterus. Examples : egg jelly (frog's eggs), shell, shell membranes and albumen (egg of reptiles, birds and egg laying mammals).

- **Types of Eggs.** Based on the quantity of yolk, the eggs are of the following types.

(i) **Microlecithal eggs.** They contain very small amount of yolk. Examples: eggs of

sea urchin, tunicates, amphioxus. In marsupials (kangaroo) eggs contain very little amount of yolk and hence these eggs are called **microlecithal**, however, human egg is **alecithal** (almost free of yolk).

(ii) **Mesolecithal eggs**. With moderate amount of yolk, e.g., eggs of *Petromyzon* (lamprey), lung fish, frogs and toads.

(iii) **Macrolecithal or Polylecithal eggs**. They contain large amount of yolk, e.g., eggs of insects, sharks, bony fishes, reptiles, birds and prototherian mammals.

Based on the distribution of yolk in the cytoplasm eggs are of the following types.

(i) **Homolecithal eggs**— the yolk is uniformly distributed all over the ooplasm (cytoplasm of the egg), e.g., eggs of echinoderms and potochordates.

(ii) **Telolecithal eggs**— the yolk is concentrated in the vegetal half, e.g., eggs of amphibians.

(iii) **Meiolecithal eggs**— the yolk is very large which occupies nearly the entire ooplasm, leaving free only a small disc-like area of cytoplasm for the nucleus, e.g., eggs of reptiles, birds and egg laying mammals.

(iv) **Centrolecithal eggs**— the yolk is localized at the centre, e.g., eggs of insects.

• **Types of cleavage**. Based on the amount and pattern of distribution of yolk in the zygote, cleavage is of two types: holoblastic and meroblastic.

1. **Holoblastic cleavage**. It divides the zygote and blastomeres completely into daughter cells. It is of two types: equal and unequal.

(i) **Equal Holoblastic cleavage**. It forms equal blastomeres. It occurs in star fish.

(ii) **Unequal Holoblastic cleavage**. It forms unequal blastomeres. Blastomeres are **micromeres** (smaller) and **macromeres** (larger). It is found in frog.

2. **Meroblastic cleavage**. In this type of cleavage, the divisions are confined to the animal pole or peripheral region of egg. The yolk remains undivided. It is of two types: discoidal and superficial.

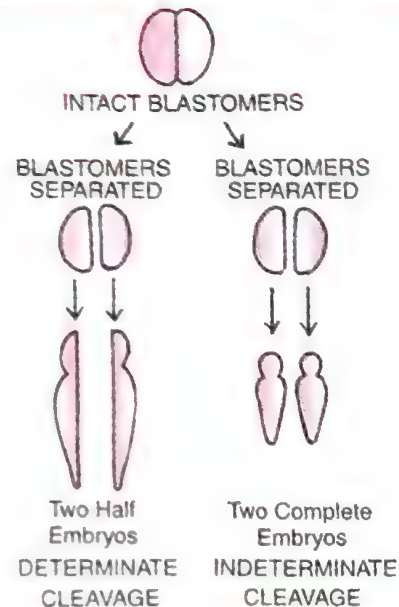
(i) **Discoidal cleavage**. The divisions are confined to the **cytoplasmic disc** located at the animal pole. It occurs in reptiles, birds and egg laying mammals.

(ii) **Superficial cleavage**. The cleavage remains restricted to the peripheral portion

of the egg. It occurs in arthropods especially insects.

Based on the potentiality of the blastomeres, cleavage is of two types:

1. **Determinate (Mosaic) cleavage**. In this type of cleavage a complete embryo is formed only if all the blastomeres remain together, e.g., annelid eggs.



2. **Indeterminate (Nonmosaic) cleavage**. In this type of cleavage each early blastomere on separation from other blastomeres may give rise to complete embryo, e.g., chordate eggs.

• **Gynecomastia**. Sometimes, the mammary glands become functional in the males too. It is called gynecomastia.

• Of the total volume of human semen more than 50% contribution comes from seminal vesicles and 15% from the prostate.

• **PSA—Prostate Specific Antigen Test**

• **Polarity**. The existence of a definite axis in the egg embryo is called polarity.

• **Primordial germ cells (PGCs)**. The cells from which the definitive germ cells are derived.

• **Gastrular Movements**. These are of two main types:

1. **Epiboly**. Epiboly means **overgrowth** of the micromeres. It occurs in frog where the micromeres divide rapidly in the animal half and spread over the megameres in the vegetal half.

2. **Emboly**. Migration of prospective endodermal and mesodermal cells from the surface into the interior of the embryo is

called emboly. It includes invagination, involution, ingression and delamination.

(i) **Invagination.** It is the process of infolding or inpushing of the vegetal pole of the embryo (blastula) into its cavity (blastocoel), forming a double-walled structure. It is just like the pushing in one side of a rubber ball with a thumb. Invagination occurs in the blastula of frog.

(ii) **Involution.** Involution is the process of rolling or turning in of the surface cells into the interior of the embryo. It occurs in frog's blastula.

(iii) **Ingression.** The term ingression means 'inward migration'. In ingression the blastomeres form new cells from their surface.

New cells migrate into the blastocoel of the blastula to form a **solid gastrula** or **stergastrula** without archenteron (primitive cavity). Archenteron is formed later by splitting the internal cell mass. Ingression is of two kinds.

(a) **Unipolar Ingression.** Inward migration of cells is restricted to the vegetal pole only. It is seen in *Obelia*.

(b) **Apolar Ingression.** Inward migration of cells occurs from all sides of the blastoderm (wall of blastula). It occurs in *Hydra*.

(iv) **Delamination.** Delamination is a process in which the separation of a layer of cells occurs from the original layer of the blastula. It occurs during gastrulation of chick and rabbit.

Gestation Period in Some Mammals

Animal	Gestation Period (in days)	Animal	Gestation Period (in days)
Ass	365-370	Lion	105-115
Cow	282	Monkey (Rhesus)	164
Cat	63	Mouse	19-20
Dog	60-63	Human being	270 days (approximately)
Elephant	624	It is usually about	266 days.
Goat	148	Rabbit	32
Horse	335-340	Sheep	148
Whale	330-365	Tiger	155

- **Twins (i) Fraternal Twins (dizygotic or non-identical twins).** Two offspring that have developed in the uterus at the same time but are the result of independent fertilization of two ova. (ii) **Monozygotic Twins (identical twins).** Two offspring developed from a single fertilized ovum. At an early stage the zygote (fertilized ovum) separates into two independent cells that develop into offspring of the same sex with identical genetic characteristics. (iii) **Siamese Twins (United Twins).** Named after **Chang** and **Eng** born in **Siam (Thailand)**. Their parents were Chinese. Siamese twins are joined in a small area. Now modern surgical techniques have made it possible to separate infants.

- **Freemartin** is a sexually undeveloped female calf twined with a male.

• Types of Placenta

1. **Classification of placenta according to the nature of the foetal membranes involved**

(i) **Yolk sac placenta.** Placenta is formed from yolk sac and chorion, e.g., Kangaroo and opossum (both are metatherians or marsupials).

(ii) **Chorio-allantoic placenta.** Placenta is derived from allantois and chorion; e.g., most eutherian mammals.

(iii) **Chorionic placenta.** Placenta is formed from chorion, e.g., human beings.

2. **Classification of placenta according to the histology.** Six tissue barriers in placenta are (1) Endothelium of foetal blood vessels (2) Foetal connective tissue (3) Trophoblast (4) Uterine epithelium (5) Uterine connective tissue and (6) Endothelium of maternal blood vessels. Five histological types of placenta are present.

(i) **Epitheliochorial placenta.** All six tissue barriers (layers) of the placenta are present, e.g., horse, ass and pig.

(ii) **Syndesmochorial placenta.** Uterine epithelium is absent; with five placental

barriers, e.g., cow, sheep, goat, buffalo, camel and giraffe.

(iii) **Endotheliochorial placenta.** Uterine epithelium and uterine connective tissue are absent; with four placental barriers, e.g., carnivores (dog, cat, lion, tiger, fox, bear and mongoose).

(iv) **Haemochorial placenta.** All the three uterine tissue barriers (uterine epithelium, uterine connective tissue and endothelium of maternal blood vessels) are absent; with three placental barriers, e.g., lemur, apes and men.

(v) **Haemoendothelial placenta.** All the three uterine tissue barriers and two foetal tissue barriers (foetal connective tissue and trophoblast) are absent; with only one placental barrier, e.g., rabbit, rat and guinea pig.

3. Classification of placenta according

to the fate of uterine placenta

(i) **Non-deciduate placenta.** No part of uterine placenta is shed in the after birth, e.g., horse, ass and zebra.

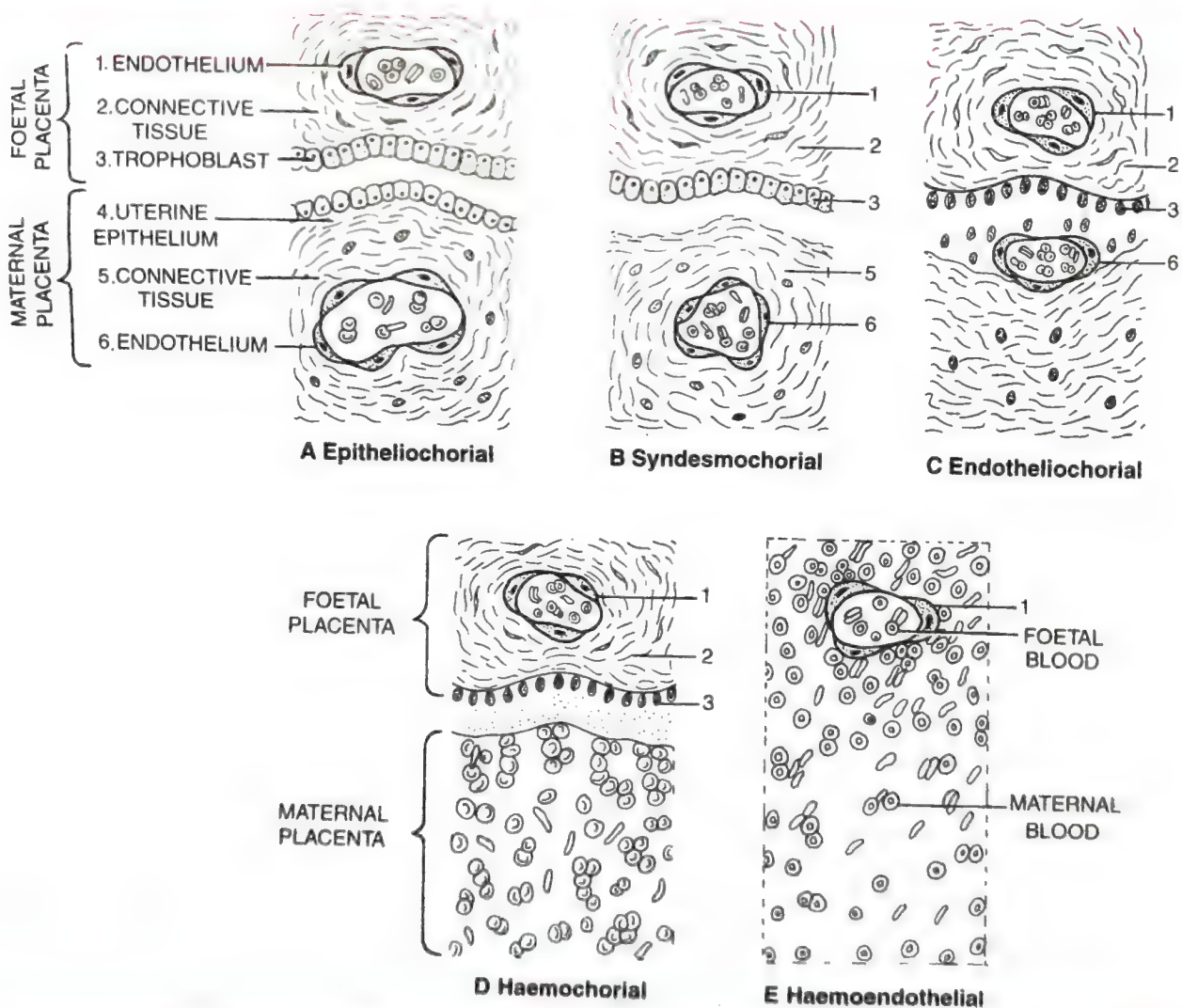
(ii) **Deciduate placenta.** Some part of uterine tissue is passed out as decidua in the after birth, e.g., humans.

(iii) **Contra-deciduate placenta.** Placenta is non-deciduate and even the foetal placenta is absorbed, e.g., *Talpa* (mole) and *Perameles* (bandicoot).

4. Classification of placenta according to the distribution of villi on chorion

(i) **Diffuse placenta.** The villi remain scattered all over the surface of the chorion, e.g., pig, horse and lemur.

(ii) **Cotyledonary placenta.** The villi are arranged in separate tufts or patches called cotyledons, e.g., cow, goat, sheep and deer.



Types of placenta according to histology.

(iii) **Intermediate placenta.** The villi are arranged in cotyledons as well as scattered, e.g., camel and giraffe.

(iv) **Zonary placenta.** The villi form an incomplete (example racoon) or complete girdle encircling the blastocyst, e.g., cat, dog, seal and elephant.

(v) **Discoidal placenta.** Villi occur on a small disc-shaped area of the blastocyst, e.g., rat, rabbit, bear and bat.

(vi) **Metadiscoidal placenta.** Villi first occur all over but later become restricted to one or two discs. (a) **Monodiscoidal placenta.** Villi are restricted to one circular disc, e.g., rabbit and man. (b) **Bidiscoidal placenta.** Villi are restricted to two discs e.g., monkey and apes.

- **Hippocrates** (460-377 B.C) observed the development of the hen's egg.
- **Aristotle** (384-322 B.C.) is regarded as the father (founder) of **embryology**. He studied the embryonic development of the chick and of many other animals and wrote the famous *Book De Generatione Animalium*.
- **Leeuwenhoek** (1632-1723) discovered human spermatozoa in 1675 in the semen with self-designed microscope.
- **Steno** introduced the word 'ovary' in 1667.
- **Regner de Graaf** (1641-1673) discovered follicles in human ovary in 1671 and considered them to be eggs. Since Graaf discovered follicles, they are also called **Graafian follicles**.
- **Swammerdam** (1738) observed the first cleavage of frog.
- **Charles Bonnet** (1720-1793) discovered natural parthenogenesis. He also gave the term parthenogenesis.
- **Karl Ernst von Baer** (1792-1876) is regarded as the "**father of modern embryology**". He discovered mammalian ova in 1827. He forwarded the **germ layer theory**.
- **C.H. Pander** (1817) first gave description of three **germ layers** in chick embryo.
- **Prevost and Dumas** (1824) were the first to describe cleavage in the eggs of frog.
- **Schleiden and Schwann** (1838-39) established the cellular nature of sperm and ova.
- **Wilhelm Roux** (1850-1924) was pioneer in experimental embryology. He is regarded as '**father of experimental embryology**'. He proposed mosaic theory of development.

● **Oscar Hertwig** (1849-1922) described the union of the nuclei of sperm and the ovum during fertilization in sea urchin. **Hertwig** (1896) induced parthenogenesis in ripe ova of sea urchin by treating those with chloroform or strychnine.

● **Hans Spemann** (1869-1941) was awarded the 1935 Nobel Prize in Physiology or Medicine for his discovery of organizer effect in embryonic development. When one embryonic tissue transmits a stimulus that influences another tissue to produce a structure that otherwise would not come into being, then the former tissue is called **organizer** or **inducer** and its morphogenic effect is called **induction**. He worked on newt.

● **Wilmut** cloned Dolly (a sheep), the world's first cloned mammal in 1997.

● The desert-grassland whiptail lizard *Cnemidophorus uniparens*, is an all female species. There are no males. It reproduces by parthenogenesis.

● The cavity of uterus can expand 500 times during pregnancy, from 10 cm³ to 5,000 cm³.

● Mammalian egg lacks centrosome. It is provided by the sperm during fertilization.

● **Pseudopregnancy.** A condition in which symptoms resembling those of pregnancy are present, but it is not pregnancy. It occurs after sterile copulation in mammals in which copulation induces ovulation.

● The ovum or egg cell is the largest cell in the human body.

● **Cleidoic eggs.** The eggs which are self sufficient (except for O₂ intake and CO₂ out flow) are called cleidoic eggs. Many reptiles (except turtles which lay eggs on damp sand), all birds and terrestrial arthropods have cleidoic eggs.

● Intra-abdominal testes are found in monotremata (egg laying mammals), proboscidea (elephants), cetacea (whales, etc.) and several insectivora.

● *Ascaris* has paired ovaries and an unpaired testis.

● Sperm of *Ascaris* lacks flagellum (tail). It is amoeboid shaped.

● **Spermiation** is the process of release of the spermatozoa from the seminiferous tubules.

● **LH. Surge** refers to the (peak maximum) level of LH during middle of menstrual cycle.

- **Foetal Ejection Reflex.** The initial mild contraction of the uterus initiated by the fully developed foetus and the placental hormones, constitute the foetal ejection reflex.
- The penis of most bats, insectivores, rodents (e.g., rats), carnivores (e.g., dog, walrus), whales and some primates (not man) have a bone called **baculum**.
- Sperm entry into the ovum stimulates the production of MPF (M-phase promoting factor) and APC (Anaphase promoting complex) which complete the meiosis-II.
- In a mother with diabetes mellitus, the foetus shall be high birth weight.
- **Hypomastia.** Abnormal smallness of breasts and mammary glands.
- **Hypermastia.** (i) Excessive growth of mammary glands. (ii) Presence of more than normal number of mammae.
- **Oligospermia.** Decreased sperm count.
- **Asthenozoospermia.** Reduced sperm motility.
- **Azoospermia.** Absence of living spermatozoa (sperms) in the semen.
- **Nebenkern.** A two stranded helical structure of the proximal region of the tail of a spermatozoon. It is derived from clumped mitochondria. (NEET-II-2016)

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. Fill in the blanks :

- (a) Humans reproduce _____ (asexually/sexually)
 - (b) Humans are _____ (oviparous, viviparous, ovoviviparous)
 - (c) Fertilisation is _____ in humans (external/internal)
 - (d) Male and female gametes are _____ (diploid/haploid)
 - (e) Zygote is _____ (diploid/haploid)
 - (f) The process of release of ovum from a mature follicle is called _____
 - (g) Ovulation is induced by a hormone called _____
 - (h) The fusion of male and female gametes is called _____
 - (i) Fertilisation takes place in _____
 - (j) Zygote divides to form _____ which is implanted in uterus.
 - (k) The structure which provides vascular connection between foetus and uterus is called _____
- ✓ (a) sexually (b) viviparous (c) internal (d) haploid (e) diploid (f) ovulation (g) luteinising hormone (LH) (h) fertilization (i) ampulla of oviduct (Fallopian tube) (j) blastocyst (k) placenta.

2. Draw a labelled diagram of male reproductive system.

✓ Refer to Male Reproductive System.

3. Draw a labelled diagram of female reproductive system.

✓ Refer to Female Reproductive System.

4. Write two major functions each of testis and ovary.

✓ **Testis.** (i) Production of sperms by seminiferous tubules.

(ii) Production of male sex hormones by Leydig cells.

Ovary. (i) Production of ova by germinal epithelium of ovary.

(ii) Production of female sex hormones by Graafian follicles and corpus luteum.

5. Describe the structure of a seminiferous tubule.

✓ Refer to text Human Male Reproductive System.

6. What is spermatogenesis ? Briefly describe the process of spermatogenesis.

✓ Refer to text Spermatogenesis.

7. Name the hormones involved in regulation of spermatogenesis ?

✓ GnRH, LH (= ICSH), FSH, androgen – binding protein (ABP), inhibin, androgens.

8. Define spermiogenesis and spermiation ?

✓ **Spermiogenesis.** The process involving transformation of spermatids into mature spermatozoa is called spermiogenesis.

Spermiation. The process of release of mature spermatozoa from Sertoli cells into the cavity of seminiferous tubules is called spermiation.

9. Draw a labelled diagram of sperm.
✓ Refer to the heading Spermatozoan (Sperm).
10. What are the major components of seminal plasma ?
✓ Fructose, calcium and certain enzymes are the major components of seminal plasma. It is a mixture of secretions from seminal vesicles, prostate and bulbourethral glands.
11. What are the major functions of male accessory ducts and glands ?
✓ **Major functions of male accessory ducts** are (i) aid in sperm transport. (ii) temporary storage of spermatozoa.
Major functions of male accessory glands. These glands secrete various secretions that constitute the part of seminal plasma. These secretions are rich in fructose, ascorbic acid, citrate, prostaglandins and some enzymes.
12. What is oogenesis ? Give a brief account of oogenesis.
✓ Refer to the text Oogenesis.
13. Draw a labelled diagram of a section through ovary.
✓ Refer to the text Human Female Reproductive System.
14. Draw a labelled diagram of a Graafian follicle ?
✓ Refer to the text Female Reproductive System.
15. Name the functions of the following : (a) Corpus luteum (b) Endometrium (c) Acrosome (d) Sperm tail (e) Fimbriae.
✓ (a) **Corpus Luteum** secretes progesterone, relaxin, inhibin/actin hormones. **Progesterone** stimulates the uterine glands to produce increased amounts of watery fluids. It also increases endometrium of the uterus. It also maintains pregnancy (placenta formation). **Relaxin** increases the flexibility of the pubis symphysis of the pelvic girdle at the time of child birth.
Inhibin/actin. Inhibin inhibits and actin activates the FSH and GnRH production.
(b) **Endometrium.** It undergoes cyclic changes during different phases of menstrual cycle. Implantation of blastocyst takes place on endometrium.
(c) **Acrosome** contains hydrolytic enzymes which are used to contact and penetrate the ovum (egg) during fertilization.
(d) **Sperm tail** helps in the locomotion of spermatozoan (sperm) in a fluid medium.
(e) **Fimbriae** bear cilia which beat towards the ostium to direct the ovum (egg) into the infundibulum.
16. Identify True/False statements. Correct each false statement to make it true.
(a) Androgens are produced by Sertoli cells. (True/False)
(b) Spermatozoa get nutrition from Sertoli cells. (True/False)
(c) Leydig cells are found in ovary. (True/False)
(d) Leydig cells synthesise androgens. (True/False)
(e) Oogenesis takes place in corpus luteum. (True/False)
(f) Menstrual cycle ceases during pregnancy. (True/False)
(g) Presence or absence of hymen is not a reliable indicator of virginity or sexual experience
✓ (a) **False.** Androgens (e.g., testosterone) is produced by Leydig's cells. (b) **True.** (c) **False.** Leydig's cells are found in testis. (d) **True.** (e) **False.** Oogenesis takes place in ovary. (f) **True.** (g) **True.**
17. What is menstrual cycle ? Which hormones regulate menstrual cycle ?
✓ The cyclic changes that take place in the female reproductive system for gamete formation in certain primates (e.g., human beings), constitute menstrual cycle.
The hormones that regulates menstrual cycles are (i) FSH (follicle stimulating hormone), (ii) LH (Luteinizing hormone), (iii) Oestrogens, (iv) Progesterone.
18. What is parturition ? Which hormones are involved in induction of parturition ?
✓ Expulsion of the foetus at the end of pregnancy is called parturition (child birth).
The hormones involved in the induction of parturition are **oxytocin** and **relaxin**.

19. In our society the women are often blamed for giving birth to daughters. Can you explain why this is not correct ?
✓ Refer to the heading Sex of the Baby.
20. How many eggs are released by a human ovary in a month ? How many eggs do you think would have been released if the mother gave birth to identical twins ? Would your answer change if the twins born were fraternal ?
✓ Generally one, rarely two, One, Yes, fraternal twins are born due to fertilization of two or more eggs.
21. How many eggs do you think were released by the ovary of a female dog which gave birth to 6 puppies ?
✓ Six eggs

TEXT QUESTIONS

One Mark Questions (With Answers)

- What is follicular atresia ?
✓ It refers to regression and disappearance of a number of follicles in the ovary of human female from birth to puberty.
- What are stem cells in human embryo ?
✓ Those cells in the inner cell mass of blastocyst which have the potency to give rise to all tissues and organs are called stem cells.
- Name any three pregnancy hormones.
✓ Progesterone, Human chorionic gonadotropin (hCG) Relaxin.
- Define foetal ejection reflex.
✓ Foetal ejection reflex refers to the initial mild contractions of the uterus, initiated by the fully developed foetus and the placental hormones.
- Name the hormone responsible for the vigorous contractions of the uterine muscles.
✓ Oxytocin
- How many spermatozoa will be produced from 100 primary spermatocytes and how many ova will be produced from 100 primary oocytes ?
✓ 400 sperms and 100 ova will be produced.
- What is spermiation ?
✓ It is the process of release of spermatozoa from the seminiferous tubules.
- What is capacitation with reference to sperm.
✓ Changes in a mammalian sperm which prepare it to fertilize ovum is called capacitation.
- Which term is used for the process of synthesis of yolk in the oocyte ?
✓ Vitellogenesis
- Which foetal membrane takes part in the formation of placenta in man ?
✓ Chorion
- Which pituitary hormone stimulates spermatogenesis ?
✓ FSH
- Name the ovarian hormone that is essential during pregnancy.
✓ Progesterone
- Name the hormone present in urine that is secreted by the placenta and is used in the pregnancy test.
✓ hCG (human chorionic gonadotropin)
- What term is used for the cyclic pattern of reproductive activity associated with seasons in cats and dogs ?
✓ Oestrous cycle

15. What name is given to human placenta ?
✓ Chorionic placenta.
16. Name the development defect whereby the testes do not descend into the scrotum.
✓ Cryptorchidism
17. What is the other name of trophoblast cells lying over the embryonic disc ?
✓ Cells of Rauber
18. What are teratogens ?
✓ The agents which cause malformations in the developing foetus are called teratogens.
19. Name the membrane that covers the vaginal opening in the virgin ?
✓ Hymen
20. Why is urethra of male human called urinogenital canal ?
✓ Because it carries both urine and semen. (CBSE 2010)
21. Where are the sperms stored in the male ?
✓ Epididymes
22. Which part of the female genital tract acts as womb ?
✓ Uterus (CBSE 2010)
23. What is the function of Scrotum ?
✓ Thermoregulation
24. At what stage is mammalian embryo implanted in uterus ?
✓ At blastocyst stage
25. Mention the function of trophoblast in human embryo (CBSE 2011)
26. State the fate of a pair of autosomes during gamete formation. (CBSE 2017)

Two Mark Questions (With Answers)

1. What is the number of chromosomes in the following cells of human male ? (i) Spermatogonial cells, (ii) Spermatids, (iii) Primary spermatocytes and (iv) Sertoli Cells ?
✓ (i) Twenty three pairs ; (ii) Twenty three ; (iii) Twenty three pairs ; (iv) Twenty three pairs
2. What is the number of chromosomes in the following cells of a human female ? (i) Primary oocyte, (ii) ootid (iii) Secondary oocyte (iv) follicle cells
✓ (i) Twenty three pairs (ii) Twenty three
(iii) Twenty three (iv) Twenty three pairs
3. Give two differences between menarche and menopause ?

✓ Menarche	Menopause
(i) It refers to beginning of menstruation at puberty in primate/human females. In human beings menstruation begins at about 13 years of age.	(i) It refers to stoppage of menstruation and menstrual cycle, at the age of 45–55.
(ii) It marks the beginning of reproductive phase.	(ii) It marks the end of reproductive phase.

4. What is the forensic test for rape ?
✓ Semen contains fructose contributed by seminal vesicles. Fructose is not produced anywhere in the human body. Its presence in the vagina indicates sexual intercourse has occurred.
5. What structure forms the 'corpus luteum' and at what stage ? Name two hormones secreted by it ?
✓ On 15th day of menstrual cycle, the peak of luteinising hormone (LH) together with prolactin hormone, stimulate the follicular cells of the empty Graafian follicles to form a yellow body called corpus luteum. It secretes progesterone and a smaller amount of estradiol.

6. Name the hormone responsible for the descent of testes into the scrotum ? Why does a failure of the testes to result in sterility ?
✓ Descent of testes into the scrotum is regulated by FSH. Failure of the testes to descend into the scrotum causes sterility because sperm formation does not occur at the abdominal temperature.
7. What is cumulus oophorus ?
✓ The maturing oocyte adheres to the wall of the follicle through a pedicel called the cumulus oophorus. It is formed by granulosa cells and thus, remains suspended in the liquor folliculi.
8. Why is breast feeding recommended during the initial period of an infant's growth? Give reasons.
✓ (i) It provides immunity : Mother's milk is rich in antibodies like IgA. These antibodies provide protection to infant from various diseases. (ii) It provides balanced nutrition : Breast milk is rich in nutrients like fat, casein, lactose, mineral salts, etc. which are essential for the growth of baby.

(CBSE 2016)

Three Mark Questions

1. Name the hormones secreted by human placenta.
2. Describe the hormonal control of the reproductive system in human male or female.
3. Fertilisation is a physico-chemical process. Explain.
4. "A fertilized egg is a blue print of future development". Explain.
5. How does the inguinal hernia develop ?
6. What is colostrum ? How is milk production hormonally regulated ?
7. Give a schematic representation of oogenesis in humans. Mention the number of chromosomes at each stage. Correlate the life phases of the individual with the stages of the process. (CBSE 2008)
8. (a) Give a schematic representation of spermatogenesis in humans.
(b) At which stage of life does gametogenesis begin in human male and female respectively ?
(c) Name the organs where gametogenesis gets completed in human male and female respectively. (CBSE 2008)
9. (a) Draw a labelled diagram of a sectional view of human seminiferous tubule. (CBSE 2017)
(b) Differentiate between gametogenesis in human males and females on the basis of
(i) time of initiation of the process.
(ii) products formed at the end of the process. (CBSE 2008)
10. Draw a labelled diagram of the microscopic structure of a human sperm. (CBSE 2008)
11. Where are the Leydig cells present ? What is their role in reproduction? (CBSE 2009)
12. Study the flow chart given below. Name the hormones involved at each stage and explain their functions.

Hypothalamus



Pituitary



Ovary



Pregnancy

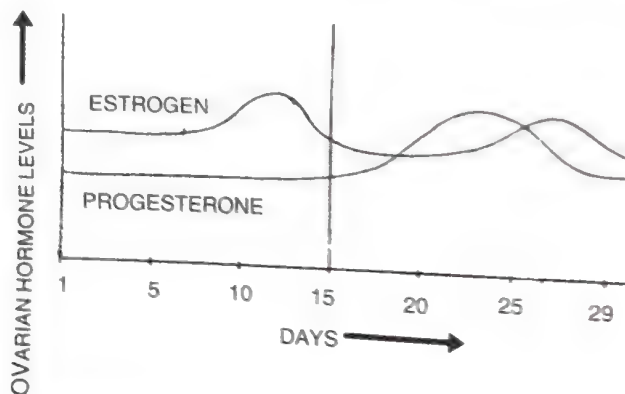
(CBSE 2009)

13. Draw a labelled diagram of human female reproductive system.
14. Describe the ultrastructure of human sperm with the help of labelled diagram.
15. Draw a labelled diagram of human male reproductive system.
16. Draw a labelled diagram of a section through ovary.
17. How and at what stage of menstrual cycle is corpus luteum formed in human females ? When does it regress ? (CBSE 2010)
18. (a) When does oogenesis begin ?
(b) Differentiate between the location and function of Sertoli cells and Leydig cells. (CBSE 2010)

19. Draw a labelled diagram of the reproductive system in a human female. (CBSE 2011)
20. When and where do chorionic villi appear in humans? State their function. (CBSE 2013)
21. Explain the steps in the formation of an ovum from an oogonium in humans. (CBSE 2013)
22. How is 'oogenesis' markedly different from 'spermatogenesis' with respect to the growth till puberty in the humans? (CBSE 2014)

Five Mark Questions

1. What are foetal membranes? Give their names. Mention the function of each.
2. Describe the development of man upto the formation of three germ layers.
3. What is oogenesis? Give a brief account of oogenesis.
4. What is spermatogenesis? Briefly describe the process of spermatogenesis.
5. Briefly describe the human female reproductive system with suitable diagram.
6. Define gametogenesis. Name two types of gametogenesis. Give a Schematic representation of spermatogenesis in humans.
7. (a) Draw a diagrammatic sectional view of human ovary to show the development of follicles and ovulation. Label the different stages in the diagram. (CBSE 2010)
(b) Why are the human testes situated in the scrotum outside the abdomen? (CBSE 2010)
8. Explain the process of fertilisation of an ovum and the events that follow till implantation in a human female. (CBSE 2010)
9. What are foetal membranes? Give their names. Mention the function of each membrane. (PSEB 2010)
10. (a) Mention the event that induces the completion of the meiotic division of the secondary oocyte.
(b) Trace the journey of the ovum from the ovary, its fertilisation and further development until the implantation of the embryo. (CBSE 2010)
11. Read the graph given below and correlate the uterine events that take place according to the hormonal levels on



- (i) 6 – 15 days
- (ii) 16 – 25 days
- (iii) 26 – 28 days (if the ovum is not fertilised)
- (b) Specify the sources of the hormones mentioned in the graph.
12. (a) When and how does placenta develop in human female? (CBSE 2008)
(b) How is the placenta connected to the embryo?
(c) Placenta acts as an endocrine gland. Explain.
13. (a) Draw a labelled diagram of the human female reproductive system. (CBSE 2009)
(b) Enumerate the events in the ovary of a human female during — (i) Follicular phase; (ii) Luteal phase of menstrual cycle. (CBSE 2011)
14. (a) Draw a diagrammatic sectional view of a human seminiferous tubule, and label Sertoli cells, primary spermatocyte, spermatogonium and spermatozoa in it.

- (b) Explain the hormonal regulation of the process of spermatogenesis in humans. (CBSE 2013)
15. Describe the roles of pituitary and ovarian hormones during the menstrual cycle in a human female. (CBSE 2015)
16. (a) Briefly explain the events of fertilisation and implantation in an adult human female.
(b) Comment on the role of placenta as an endocrine gland. (CBSE 2016)
17. (a) Arrange the following hormones in sequence of their secretion in a pregnant woman.
(b) Mention their source and the function they perform. hCG; LH; FSH; Relaxin. (CBSE 2017)
18. (a) Explain the following phases in the menstrual cycle of a human female.
(i) Menstrual phase; (ii) Follicular phase; (iii) Luteal phase.
(b) A proper understanding of menstrual cycle can help immensely in family planning. Do you agree with the statement? Provide reasons for your answer. (CBSE 2017)

Value Based Questions With Answers

1. Rashmi gave birth to three girls. Her mother-in-law blamed her for giving birth to girls. However, as we know ova (eggs) are only of one type containing 22+X chromosomes but sperms are of two types : one type of sperms contain 22 + X chromosomes and another type of sperms contain 22 + Y chromosomes. When ovum and sperm with 22 + Y chromosomes are fused male child is formed and when ovum and sperm with 22 + X chromosomes are fused girl child is produced.

Read the above passage and answer the following questions.

- (i) In your opinion, who is responsible for female child (mother or father).
(ii) How many types of sperms are produced.
(iii) Penetration of which type of sperm into ovum produces male child.

- ✓ (i) Father
(ii) Two types
(iii) Sperm containing 22 + Y chromosomes

2. Mahesh was working in Delhi but his family was living in the village. One day he received a letter from his father that he is planning marriage of her sister who is fourteen years old. Mahesh wrote to his father that he should postpone the marriage of his sister till she becomes 18 year old.

Read the above passage and answer the following questions :

- (i) Who is right mahesh or his father ?
(ii) What is the right age of marriage for girls?
(iii) What are the risks involved in early marriage?

- ✓ (i) Mahesh is right
(ii) 18 years

(iii) Female reproductive organs below 18 years are not fully prepared for pregnancy. Early pregnancy may have harmful effects on the health of the mother.

3. Rekha told her friend Babita that even after four years of marriage she is not able to bear a child and sarcastic remarks of her in-laws make her depressed. Rekha told Babita that she and her husband should get examined by a doctor. After examination, doctor found no abnormalities in Rekha and his husband except low sperm count of her husband. Rekha told her friend that her husband takes alcohol, drugs and smoke daily. Her husband has some defects in the erection of penis.

Read the above passage and answer the following questions :

- (i) What are the possible causes of low sperm counts ?
(ii) What is the use of erection of penis ?
✓ (i) Use of alcohol, drugs and smoking may cause decrease in sperm counts.
(ii) If a man is unable to erect his penis properly, he is unable to perform intercourse and semen containing sperms can not be introduced into the vagina in required amount.

4. Parveen is a modern working woman. She gave birth to a baby three weeks ago. She has hectic schedule. She requested her mother-in-law to feed the powdered milk to the baby. However, her mother-in-law asked her for breast feeding.

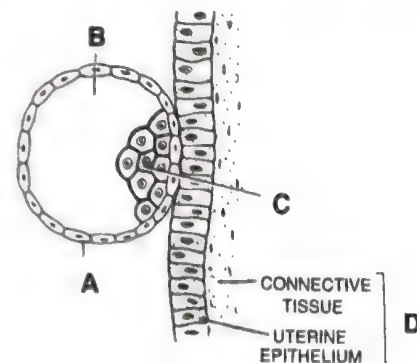
Read the above passage and answer the following questions

- (i) Who is right Parveen or her mother-in-law?
- (ii) Why is breast feeding important?
- (iii) If Parveen does not breast feed the baby, what health problem she can face?
 - ✓ (i) Parveen's mother-in-law is right.
 - (ii) Mother's milk is perfect food for infants. It also protects infant from infections. Breast feeding also prevents pregnancy and therefore, helpful in birth control.
 - (iii) Hormonal balance in the body of the mother may be disturbed. She may develop breast cancer.

Multiple Choice Questions (With Answers)

- (1) In human, the unpaired male reproductive structure is (a) seminal vesicle (b) prostate (c) bulbourethral gland (d) testes (e) vas deferens. *(Kerala PMT 2010)*
- (2) Stereocilia occur in (a) pseudostratified columnar epithelium of trachea (b) columnar epithelium of stomach (c) stratified columnar epithelium of pharynx (d) pseudostratified columnar epithelium of epididymis. *(AMU 2010)*

- (3) In the diagram of implantation of blastocyst, choose the correct match. (a) A = Blastocyst cavity, B = Trophoblast, C = Inner cell mass, D = Endometrium of uterus ; (b) A = Trophoblast, B = Blastocyst cavity, C = Inner cell mass, D = Endometrium of uterus ; (c) A = Blastocyst cavity, B = Trophoblast, C = Endometrium of uterus, D = Inner cell mass; (d) A = Inner cell mass, B = Trophoblast, C = Endometrium of uterus, D = Blastocyst cavity



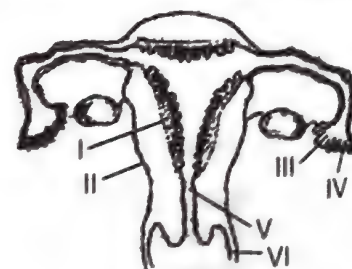
- (4) In human female the blastocyst
 - (a) forms placenta even before implantation (b) gets implanted into uterus 3 days after ovulation (c) gets nutrition from uterine endometrial secretion only after implantation (d) gets implanted in endometrium by the trophoblast cell.
- (5) What happens during fertilization in humans after many sperms reach close to the ovum ?
 - (a) Secretions of acrosome help one sperm enter cytoplasm of ovum through zona pellucida (b) all sperms except the one nearest to the ovum lose their tails (c) cells of corona radiata trap all the sperms except one (d) only two sperms nearest the ovum penetrate zona pellucida.

(CBSE PMT Mains 2010)

- (6) The figure given depicts a diagrammatic sectional view of the human female reproductive system. Which set of three parts out of I-VI have been correctly identified ?

(a) (II) endometrium, (III) infundibulum, (IV) fimbriae (b) (III) infundibulum, (IV) fimbriae, (V) cervix (c) (IV) oviducal funnel, (V) uterus, (VI) cervix (d) (I) perimetrium, (II) myometrium, (III) Fallopian tube.

(AIPMT (Prelims) 2011)



- (7) Name the hormone that has no role in menstruation
 - (a) LH (b) FSH (c) GH (d) TSH.

(West Bengal JEE 2011)

- (8) Column I contains terms and Column II contains definitions. Match them correctly and choose the right answer.

Column I

- A Parturition
B Gestation
C Ovulation
D Implantation
E Conception

Column II

1. Attachment of zygote to endometrium
2. Release of egg from Graafian follicle
3. Delivery of baby from uterus
4. Duration between pregnancy and birth
5. Formation of zygote by fusion of the egg and sperm
6. Stoppage of ovulation and menstruation

- (a) A - 2, B - 4, C - 1, D - 5, E - 3
 (b) A - 4, B - 3, C - 1, D - 5, E - 2
 (c) A - 5, B - 1, C - 2, D - 3, E - 4
 (d) A - 3, B - 4, C - 2, D - 1, E - 5

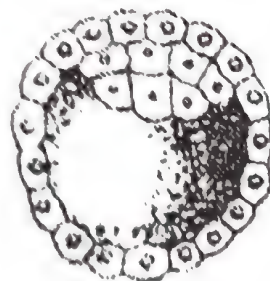
(Karnataka CET 2011)

- (9) Sperm acrosome is derived from (a) Golgi body (b) endoplasmic reticulum (c) lysosome (d) mesosome.
 (J & K CET 2011)
- (10) In human females, the ovarian cycle begins when the (a) levels of oestrogen reach their maximum (b) hypothalamus stimulates the anterior pituitary to increase its output of FSH and LH (c) level of progesterone drops precipitously (d) hypothalamus increases its release of FSH and LH.
 (J & K CET 2012)
- (11) The secretory phase in the human menstrual cycle is also called (a) luteal phase and lasts for about 6 days (b) follicular phase and lasts for about 6 days (c) luteal phase and lasts for about 13 days (d) follicular phase and lasts for about 13 days
 (CBSE PMT Mains 2012)
- (12) Identify the human development stage shown below as well as the related right place of its occurrence in a normal pregnant woman and select the right option for the two, together

Developmental stage

Site of occurrence

- (a) Late morula - middle part of Fallopian tube
 (b) Blastula - end part of Fallopian tube
 (c) Blastocyst - uterine wall
 (d) 8-celled morula - starting point of Fallopian tube



(CBSE Mains 2012)

- (13) What is the correct sequence of sperm formation? (a) Spermatogonia, spermatozoa, spermatocyte, spermatid (b) Spermatogonia, spermatocyte, spermatid, spermatozoa (c) Spermatid, spermatocyte, spermatogonia, spermatozoa (d) Spermatogonia, spermatocyte, spermatozoa, spermatid.
 (NEET 2013)
- (14) Which one of the following is not the function of placenta? (a) Facilitates removal of carbon dioxide and waste material from embryo (b) Secretes oxytocin during parturition (c) Facilitates supply of oxygen and nutrients to embryo (d) Secretes estrogen.
 (NEET 2013)
- (15) Menstrual flow occurs due to lack of (a) oxytocin (b) vasopressin (c) progesterone (d) FSH.
 (NEET 2013)
- (16) GnRH secreted from hypothalamus mainly stimulates the release of (a) Thyroxine from thyroid gland (b) ADH from posterior pituitary (c) FSH and LH from anterior pituitary (d) Aldosterone from adrenals.
 (AMU 2013)
- (17) Which of the following is not a function of progesterone? (a) Gestation (b) Inhibition of ovulation (c) Uterine growth and development (d) Stimulation of mammary secretion.
 (AMU 2013)
- (18) Secretion of progesterone by corpus luteum is initiated by (a) GH (b) LH (c) thyroxine (d) testosterone.
 (J & K CET 2013)
- (19) The function of oxytocin is to help in (a) child birth (b) growth (c) lactation (d) gametogenesis.
 (J & K CET 2013)
- (20) Human gametes differ from all other body cells as they are (a) motile (b) diploid (c) haploid (d) without cell wall.
 (J & K CET 2013)
- (21) Which one of the following is initiated by secretions of trophoblast? (a) Blastulation (b) Gastrulation (c) Implantation (d) Cleavage.
 (J & K CET 2013)
- (22) "Testis are extra-abdominal in position". Which of the following is most appropriate reason?
 (a) Narrow pelvis in male (b) Special protection for testis (c) Prostate gland and seminal vesicles occupy maximum space (d) 2.0-2.5°C lower than the normal body temperature.
 (Maharashtra CET 2014)
- (23) Which of the following events is not associated with ovulation in human female? (a) Decrease in

oestradiol (b) Full development of Graafian follicle (c) Release of secondary oocyte (d) LH surge.
(AIPMT 2015)

- (24) Which of the following layers in an antral follicle is acellular ?
(a) Granulosa (b) Theca interna (c) Stroma (d) Zona pellucida. (AIPMT 2015)
- (25) Select the incorrect statement (a) LH triggers ovulation in ovary (b) LH and FSH decrease gradually during the follicular phase (c) LH triggers secretion of androgens from the Leydig cells (d) FSH stimulates the Sertoli cells which help in spermiogenesis. (NEET-I-2016)
- (26) Fertilization in humans is practically feasible only if (a) the ovum and sperms are transported simultaneously to ampullary – isthmic junction of the fallopian tube (b) the ovum and sperms are transported simultaneously to ampullary – isthmic junction of the cervix (c) the sperms are transported into cervix within 48 hrs of release to ovum in uterus (d) the sperms are transported into vagina just after the release of ovum in fallopian tube. (NEET-I-2016)
- (27) Changes in GnRH pulse frequency in females is controlled by circulating levels of (a) estrogen and inhibin (b) progesterone only (c) progesterone and inhibin (d) estrogen and progesterone. (NEET-I-2016)
- (28) Identify the correct statement on 'inhibin' (a) is produced by granulosa cells in ovary and inhibits the secretion of FSH (b) is produced by granulosa cells in ovary and inhibits the secretion of LH (c) is produced by nurse cells in testes and inhibits the secretion of LH (d) inhibits the secretion of LH, FSH and prolactin. (NEET-I-2016)
- (29) Which of the following depicts the correct pathway of transport of sperms ?
(a) Rete testis → Efferent ductules → Epididymis → Vas deferens (b) Rete testis → Epididymis → Efferent ductules → Vas deferens (c) Rete testis → Vas deferens → Efferent ductules → Epididymis (d) Efferent ductules → Rete testis → Vas deferens → Epididymis. (NEET-II-2016)
- (30) Match Column I with Column II and select the correct option using the codes given below.

Column I

- A. Mons pubis
B. Antrum
C. Trophoectoderm
D. Nebenkern

Column II

1. Embryo formation
2. Sperm
3. Female external genitalia
4. Graafian follicle

Codes

- | | A | B | C | D |
|-----|---|---|---|---|
| (a) | 3 | 4 | 2 | 1 |
| (c) | 3 | 1 | 4 | 2 |

- | | A | B | C | D |
|-----|---|---|---|---|
| (b) | 3 | 4 | 1 | 2 |
| (d) | 1 | 4 | 3 | 2 |

- (31) Capacitation occurs in

- (a) epididymis (b) vas deferens (c) female reproductive tract (d) rete testis.

(NEET-II-2016)

(NEET 2017)

Assertion and Reason– Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as–

- (a) If both A and R are true and R is the correct explanation of A
(b) If both A and R are true and R is not the correct explanation of A
(c) If A is true but R is false
(d) If both A and R are false.

1. **Assertion:** Zona pellucida disappears when blastocyst reaches the uterus.
Reason: Role of zona pellucida is to check the implantation of the blastocyst at an improper site.

A B C D

2. **Assertion (A) :** Upto morula stage, the cells divide without any increase in size. (AIIMS 1997)

Reason: Zona pellucida remains intact till cleavage is complete.

A B C D

3. **Assertion (A)** : In a woman after hysterectomy (removal of uterus), the ovarian cycle is stopped.
Reason : Stoppage of FSH secretion.
 A B C D (Haryana PMT 2000)
4. **Assertion (A)** : In morula stage, the cell divides without increases in size.
Reason : Zone pellucida remains till cleavage.
 A B C D (Haryana PMT 2000)
5. **Assertion (A)** : Holoblastic cleavage, with almost equal sized blastometers is a characteristic of placental mammals.
Reason : Eggs of most mammals, including humans are of centrolecithal type :
 A B C D (AIIMS PMT 2003)
6. **Assertion** : In humans, the gamete contributed by the male determines whether the child produced will be male or female.
Reason : Sex in humans is a polygenic trait depending upon a cumulative effect of some genes on X-chromosome and some on Y-chromosome.
 A B C D (AIIMS 2005)

ANSWERS

Multiple Choice Questions

- (1) —b (2) —d (3) —b (4) —d (5) —a (6) —b (7) —d (8) —d (9) —a (10) —c
 (11) —c (12) —c (13) —b (14) —b (15) —c (16) —c (17) —d (18) —b (19) —a (20) —c
 (21) —c (22) —d (23) —a (24) —d (25) —b (26) —a (27) —d (28) —a (29) —a (30) —b
 (31) —c

Assertion and Reason —Type Questions

- (1) —A (2) —B (3) —B (4) —B (5) —D (6) —C

What is Reproductive Health ?

The term reproductive health simply refers to healthy reproductive organs with normal functions. But according to the World Health Organisation (WHO) reproductive health means a total well being in physical, emotional, social and behavioural aspects in reproduction. Thus reproductively healthy persons have physically and functionally normal reproductive organs and normal behavioural and emotional interactions among them in all sex-related aspects. Now the question arises why is it so significant to maintain reproductive health and what are the methods to achieve it ?

REPRODUCTIVE HEALTH— PROBLEMS AND STRATEGIES**Problems**

1. **Over Population.** Main problem of India is its excess population.
2. **Early Marriage.** Children are often married as soon as they attain puberty.
3. **Health of Mothers.** Early marriage leads to several diseases in mothers.
4. **Deformities.** Deformities are common in children of early marriage.
5. **Maternal Mortality Rate (MMR) and Infant Mortality Rate (IMR).** These are high in early marriage.
6. **Sexually Transmitted Diseases (STDs).** The children who have married early, they do not have proper knowledge of reproductive organs, hence the STDs are common in these persons.
7. **Carreer.** Early marriage blocks the carreer of the couple especially of the lady.

Strategies

1. **Family Planning Programme.** It was invented in 1951.
2. **Awariness about Reproduction.** Audio-visual and print media, governmental and non-governmental agencies are doing good job to create awariness among people about reproduction in humans. Parents, close relatives, friends and teachers also have a major role in giving the above information.
3. **Sex Education.** Sex education in schools should also be introduced and encouraged to provide right information about myths and misconceptions about sex-related aspects.
4. **Knowledge of growth of reproductive organs and STDs.** Proper information about reproductive organs, adolescence (period of rapid growth between childhood and adulthood), safe and hygienic sexual practices, sexually transmitted diseases (STDs), e.g., AIDS etc., would help to lead a reproductive healthy life.
5. **Birth control devices and care of mother and child.** Fertile couples and people of marriageable age group should know about available birth control devices, care of pregnant mothers, postnatal (after birth) care of the mother and child, importance of breast feeding, equal importance for the male and female child, etc.

6. **Prevention of sex abuse and sex related crime.** Awareness of problems due to uncontrolled population growth, social evils like sex abuse and sex-related crimes, etc. need to be created so that people should think and take up necessary steps to prevent them and thereby build up a reproductively healthy society.

7. **Information about reproduction related problems.** For successful action plans to attain reproductive health requires good infra structural facilities, professional expert knowledge and material support. These are necessary to provide medical help and care for reproduction related problems like menstrual problems, infertility, pregnancy, delivery, contraception, abortions, sexually transmitted diseases (STDs). Implementation of better techniques and new strategies are also required to provide better care and help to people for reproductive health.

8. **Research in reproductive health area.** It should be encouraged and supported to find out new methods. "Saheli" a new oral contraceptive for the females was developed by our scientists at Central Drug Research Institute (CDRI) in Lucknow, India.

9. **Medical facilities.** Better awareness about sex related problems, prenatal care of mother, medically assisted deliveries and post natal care of mother and infant decrease maternal and infant mortality, small families better detection and cure of sexually transmitted diseases (STDs) and increased medical facilities for sex-related problems, etc. indicate improved reproductive health of male and female individuals and children.

10. **Amniocentesis — Meaning and Use.** Amniocentesis is a foetal sex determination and disorder test based on the chromosomal pattern in the amniotic fluid surrounding the developing embryo.

Procedure. Amniotic fluid contains cells from the skin of the foetus and other sources. These cells can be used to determine the sex of the infant, to identify some abnormalities in the number of chromosomes and to detect certain biochemical and enzymatic abnormalities. If it is established that the child is likely to suffer from a serious incurable congenital defect, the mother should get the foetus aborted.

Misuse of Amniocentesis. It is being used to kill the normal female foetus. It is legally banned for the determination of sex to avoid female foeticide.

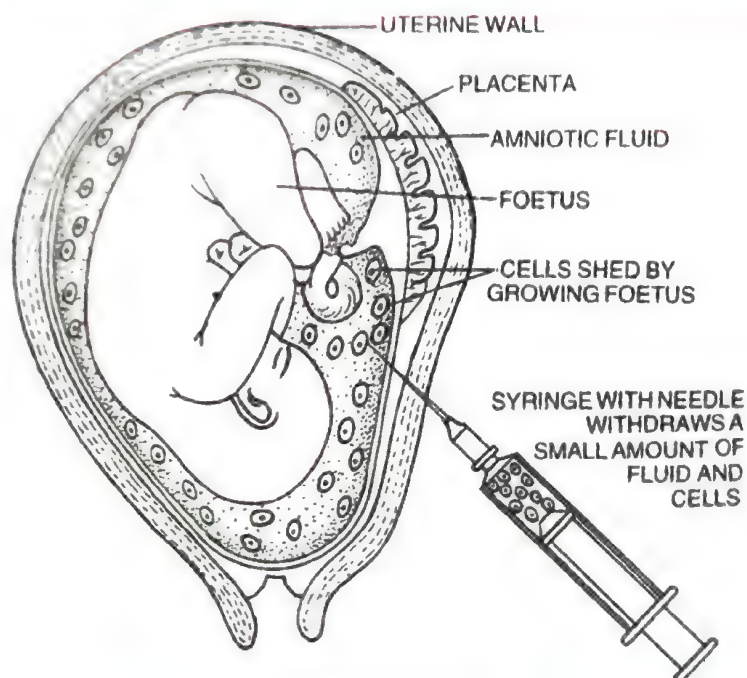


Fig. 4.1. Amniocentesis.

POPULATION EXPLOSION

Population is defined as the total number of individuals of a species present in a particular area at a given time. A species has many populations living in different regions.

The scientific study of human population is called **demography**. It deals with three phenomena;

- (1) changes in population size (growth or decline)
- (2) the composition of population and
- (3) the distribution of population in space.

It deals with five 'demographic processes' namely fertility, mortality, marriage, migration and social mobility. These five processes are continually at work within a population determining size, composition and distribution.

Human World Population	
Year	Population
1700 A.D	0.6 billion
1850	1 billion
1930	2 billion
1965	3.5 billion
1975	4 billion
1990	5 billion
2000	6.1 billion
2011	7 billion

Population Figures of Five Countries of the World 2011		
Rank	Country	Population
1.	China	13,36,71,8015
2.	India	1,210,193,422
3.	United States	313,232,044
4.	Indonesia	245,613,043
5.	Brazil	203,429,773

The rapid increase in population over a relatively short period is called **population explosion**. The world population which was around 2 billions (2000 million) in 1900 reached about 6 billions by 2000. A similar trend was observed in India too. Our population which was approximately 350 million at the time of our independence reached close to the billion mark by 2000 and crossed 1 billion in May 2000. This means, every sixth person in the world is an Indian. A rapid decline in death rate, **maternal mortality rate** (MMR) and **infant mortality rate** (IMR) and an increase in number of people in reproductive age are probable reasons for this. Through our role of **Reproductive and Child Health Care** (RCH) programmes, we could bring down the population growth rate. According to the 2001 census report, the population growth rate was still around 1.7 percent, i.e., 17/1000/year, a rate at which our population could double in 33 years. Such an alarming growth rate could lead to an absolute scarcity of food, shelter and clothing. Therefore, the government was forced to take up serious measures to check this population growth rate.

The present growth rate of human population is approximately 2.5 per cent.

Population of India 1901-2011	
Year	Population
1901	238, 396, 327
1911	252, 093, 390
1921	251, 321, 213
1931	278, 977, 238
1941	318, 660, 580
1951	361, 088, 090
1961	439, 234, 771
1971	548, 159, 652
1981	685, 148, 692
1991	843, 930, 861
2001	1,027,015,247
2011	1,210,193,422

Sex Ratio in India 1901-2011	
Year	Females per 1000 males
1901	972
1911	964
1921	955
1931	950
1941	945
1951	946
1961	941
1971	930
1981	934
1991	927
2001	933
2011	940.27

Population Growth

Four basic processes are involved in increase or decrease in the population size. Natality and immigration contribute an increase in population and mortality and emigration decrease the population.

The **population density** is the number of individuals of a species per unit area/space at a given time.

$$\text{Population Density (D)} = \frac{\text{Number of individuals (N)}}{\text{Space (S)}}$$

$$\text{or } D = \frac{N}{S}$$

- (i) **Natality.** It refers to the birth rate.
- (ii) **Mortality.** It refers to the death rate.
- (iii) **Immigration.** It is the number of individuals that have come into the habitat.
- (iv) **Emigration.** It is the number of individuals of the population who left the habitat.

Growth is of two types :— (1) **Exponential Growth.** It shows **J-shaped growth curve.** (2) **Logistic Growth.** It shows **S-shaped or Sigmoid Growth Curve.** This type of population growth is called **Verhulst-Pearl Logistic Growth** as explained by the following equation :

$$dN/dt = r N \left(\frac{K-N}{K} \right)$$

Where N = Population density at a time t ; r = Intrinsic rate of natural increase and; K = Carrying capacity.

The distribution of human population is not uniform throughout the world. Some areas are thickly populated and others are thinly populated. Monaco is the most thickly populated country. Australia is the most thinly populated country. Greenland (now called Kalallit Nunaat) — part of Denmark is least densely populated part in the world.

Census

Census is an official counting of population and preparing data about age groups, births, deaths, sex ratio, education, etc. In India, first census was carried out in 1872. Infact since 1881 it has been conducted regularly at interval of 10 years, the last being in 2011. Census is conducted as per the provision made under the Census Act 1948.

India's Census 2011

The India's census 2011 was conducted from February 9 to 28 and provisional figures of India's 15th census were released in New Delhi on 31st March 2011.

India accounts for 17.5% of the world's population.

India's Population as on March 1, 2011 :	1,210,193,422
Males :	623,724,248
Females :	586,469,174
Sex Ratio (females per 1,000 males) :	940

Density of Population in India

Year	per sq. km
1901	77
1911	82
1921	81
1931	90
1941	103
1951	117
1961	142
1971	173
1981	221
1991	267
2001	324
2011	382

Population Density (persons per sq km) :

Decadal (Period of ten years) growth rate of population between 2001-2011 : 17.64

Most Populous State : Uttar Pradesh

Least Populous State : Sikkim

Among states Kerala has the **highest sex ratio** (1084) and among Union Territories (UTs), Daman and Diu the lowest (618).

Least Populous UT : Lakshadweep

Literacy Rate : 74.04 per cent (82.14 for males and 65.46 for females)

The Highest Literacy Rate : Kerala with 93.91 per cent literacy rate

The Lowest Literacy Rate : Bihar with 63.82 per cent literacy rate

State with highest Density of population — Bihar with 1102 persons per sq. km.

State with lowest Density of population — Arunachal Pradesh with 17 persons per sq. km.

Maximum Density Among Union Territories — Delhi — National Capital Territory (NCT) with 11297 persons per sq. km. It is also most thickly populated city in India.

Lowest Density Among Union Territories — Andaman-Nicobar with 46 persons per sq. km.

Biggest State as per area — Rajasthan

Smallest State as per area — Goa

Reasons for High Population Growth

There are two main factors for the increase in human population. (A) **Decrease in death rate** mainly **maternal mortality rate** (MMR) and **infant mortality rate** (IMR) and (B) **Increase in span of life**. Reasons for growth of human population are briefly described here.

- (i) **Spread of Education.** Persons of the country are being educated about the diseases.
- (ii) **Control of Diseases.** Control of various communicable diseases is in practice.
- (iii) **Advancement in Agriculture.** Farmers are educated to develop high yielding crops.
- (iv) **Storage Facilities.** A good quantity of grains can be stored easily.
- (v) **Better Transport.** This protects from famines.
- (vi) **Protection from Natural Calamity.** It decreases death rate.
- (vii) **Government Efforts.** Government is doing efforts to provide maximum information to the farmers.

Malthus Theory of Human Population Growth

In 1798 T.R. Malthus, a British economist, put forward a theory of human population growth. (i) He stated that population grows geometrically (1, 2, 4, 8, 16, 32....) when unchecked, whereas the means of its subsistence like food grow only arithmetically (1, 2, 3, 4, 5, 6, 7....). (ii) Naturally, after some time an imbalance would occur in the population and the environment, (iii) When the imbalance reaches a certain value, some factors like hunger, epidemics, floods, earthquakes, war, etc. will bring the population to a desired level.

Such a population “crash” is called **catastrophic control of population**. These factors were called “**positive checks**” by Malthus.

Consequences of Overpopulation

Over population leads to number of not only national but also individuals family problems. Some of them are described below.

1. **Poverty.** If in a family there are more persons and the income is less, so naturally it becomes poor. With the addition of every child, the poverty increases.
2. **Food supply.** If the population increases and the production of food does not increase, this will lead to a shortage of food supply.
3. **Hygienic condition.** More people in a small area generally make the hygienic conditions bad. There will be an accumulation of waste material as it is not removed that early.
4. **Unemployment.** More number of people means more jobs and if sufficient number of jobs are not available, it leads to unemployment.
5. **Housing problem.** For more people, more houses are required and the houses are not built at high rate.
6. **Pollution.** There will be an added problem of population. As every thing is taken from environment in excess, so it will result in pollution.
8. **Education problem.** It becomes difficult for the government to provide education to all.

Population Control

1. **Education.** People, particularly those in the reproductive age group, should be educated about the advantage of a small family. Mass media and educational institutions can play an important role in this campaign. Posters showing a happy couple with two children with a slogan “Hum Do Humare Do” should be displayed. Many couples even adopted “one child norm”.
2. **Marriageable Age.** Raising of the age of marriage is more effective means to control the population (now marriageable age of female is 18 years and that of male is 21 years).
3. **Incentives.** Couples with small families should be given incentives.
4. **Family Planning.** There are many birth control measures which can check birth rate.

Census gives information about the number of individuals present in a given region at a given time. The time required for a population to double itself is called the **doubling time**.

Population Growth Rate

It is indicated by (i) the annual average growth rate and (ii) the doubling time.

Growth rate depends on birth (fertility) rate, death (mortality) rate, migration and age-sex ratio.

1. **Fertility (Natality).** Fertility is the ability of the reproductively active individuals to produce babies. **Birth rate** is the number of babies produced per thousand individuals. It differs from the population growth rate as it is never negative while the growth rate can be negative. **Total fertility rate (TFR)** is the average number of children that would be born to a woman during her lifetime. The total fertility rate varies from region to region. The more developed countries have lower fertility rates than the less developed countries. Fertility is

mainly controlled by economics and human aspirations. **Replacement level (RL)** is the number of children a couple must produce to replace themselves so as to maintain the population at zero growth level. RL is slightly higher than 2.0 because some children die before reaching reproductive age. RL is 2.1 in developed countries and 2.7 in developing countries due to a higher death rate at the immature age.

2. **Mortality.** Mortality is the death rate per thousand individuals. Death rate has fallen in most countries. It is due to improved personal hygiene, sanitation and modern medicines.

Demographers generally use crude birth rate and crude death rate. **Crude birth rate** is the number of live births per thousand persons in the middle of a given year (*i.e.*, on July 07). **Crude death rate** is the number of deaths per thousand persons in the middle of a given year (*i.e.*, on July 07). The difference between the number of births and that of deaths is called the **rate of natural increase**. If birth and death rates were equal, a zero population growth rate would result, which is known as **demographic transition**. It has occurred in most developed countries. Figure 4.5 shows the different stages of the demographic transition.

Differences between Natality Rate and Mortality Rate	
Natality Rate (Birth Rate)	Mortality Rate (Death Rate)
<ol style="list-style-type: none"> 1. It is the number of births per one thousand individuals per year. 2. It is the rate at which new members are added to a population by reproduction. 3. It increases population size and population density. 	<ol style="list-style-type: none"> 1. It is the number of deaths per one thousand individuals per year. 2. It is the rate at which the individuals die out. 3. It decreases population size and population density.

Differences between Birth Rate and Population Growth Rate	
Birth Rate	Population Growth Rate
<ol style="list-style-type: none"> 1. Birth rate is the rate of number of bodies being produced per 1000 individuals of a population per year. 2. It can never be negative. 	<ol style="list-style-type: none"> 1. Population growth rate is indicated by the annual average growth rate and the doubling time. 2. It can be negative.

3. **Migration.** Migration is the movement of individuals into or out of a place or country. Thus migration is of two types (i) **Immigration.** It is the movement of individuals into an area. (ii) **Emigration.** It is the movement of individuals out of an area. Migration may occur within a country as well as between different countries. But population of a country is influenced by net immigration. The **net immigration** is immigration minus the emigration. The net immigration may be positive, zero or even negative. Some developed countries allow selective immigration to keep its working force at optimum level.

Differences between Immigration and Emigration	
Immigration	Emigration
<ol style="list-style-type: none"> 1. It is the movement of individuals into a place or country. 2. It results in the increase in population. 	<ol style="list-style-type: none"> 1. It is the movement of individuals out of a place or country. 2. It results in the decrease in the population.

4. **Age and Sex Structures.** Bodonheimer (1958) proposed three age groups in a population — pre-reproductive, reproductive and postreproductive. Infants and older people have higher mortality rate than individuals of other ages. The proportion of reproductively active males and females in a population also influences the population growth. The birth rate is influenced by the number of female individuals who are in active reproductive age, which is generally 15–44 years.

BIRTH CONTROL

Birth control methods act by preventing any one or more of the three major steps in the reproductive processes. (a) Preventing sperm transport to the ovum. (b) Preventing ovulation and (c) Preventing implantation of early embryo in the uterus.

Various contraceptive methods are broadly grouped into two main types : spacing or temporary methods and terminal or permanent methods.

(A) Temporary Methods of Birth Control

Temporary methods are commonly used to postpone or to space births.

1. **Natural Methods.** These methods avoid meeting sperm and ovum.

(i) **Periodic absence or Rhythm Method (temporary avoidance of sex).** It is one such method in which the couples avoid or abstain from coitus (copulation or intercourse) from day 10 to 17 of the menstrual cycle because ovulation can occur during this period. The chances of fertilisation are very high during this period, therefore, it is called the fertile period.

This method is based on the following facts.

- (a) ovulation occurs on about the 14th day of menstruation.
- (b) ovum remains alive for about 1–2 days.
- (c) sperms survive for about 3 days.

The effectiveness of this method is limited because only a few women have regular menstrual cycles and the actual time of ovulation can not be produced as the ovulation in humans occurs about 14 days before the onset of the next menstruation.

(ii) **Coitus interruptus** (withdrawal method). Male withdraws his penis from the vagina just before ejaculation to avoid insemination so that semen is carried outside the vagina.

This method is only moderately effective because time of ejaculation is very pleasant specially for male. Some sperms may pass into the vagina before ejaculation.

(iii) **Lactational Amenorrhea Method—LAM** (absence of menstruation). There is no menstrual cycle, and therefore, ovulation does not occur during intense lactation following parturition. However, this method is effective only up to maximum period of six months after child birth.

2. **Barrier Methods.** In these methods ovum and sperms do not meet due to barriers. *Infact they prevent fertilization.* These methods are available for the males and the females which are as follows :

(i) **Condoms.** Condoms are made of thin rubber/ latex sheath used to cover the penis in the male or vagina and cervix in the female just before coitus (intercourse) so that the ejaculated semen is not released in the female reproductive tract. This prevents fertilization. **Nirodh** (Hindi name of Condom) is popular brand of condom for the male. Nirodh also protects the user from STDs and AIDS. Both the male and female condoms are disposable. Female condoms are known as **femidoms**.

(ii) **Diaphragms, Cervical Caps and Vaults.** These are also made of rubber, inserted into the female reproductive tract to cover the cervix before coitus. They must be left in place at least 6 hours after intercourse. They prevent fertilization by blocking the entry of sperms through the cervix. These barriers are reusable. *Spermicidal jellies, creams and foams are generally used along with these barriers to increase their efficiency.*

(a) **Diaphragm.** It is soft rubber cup that covers entrance to uterus. It prevents a sperm from reaching an egg; and holds spermicide. There are no dangerous side effects. It is reliable if used properly. It provides some protection against sexually transmitted diseases and cervical cancer.

(b) **Cervical Cap.** It is a miniature diaphragm that covers cervix closely. It prevents a sperm from reaching an egg and holds spermicide. There is no dangerous side effects. It is fairly effective and can remain in place longer than diaphragm.

(c) **Vault Cap.** It is hemispheric dome like rubber or plastic cap with a thick rim which is meant for fitting over the vaginal vault over the cervix.

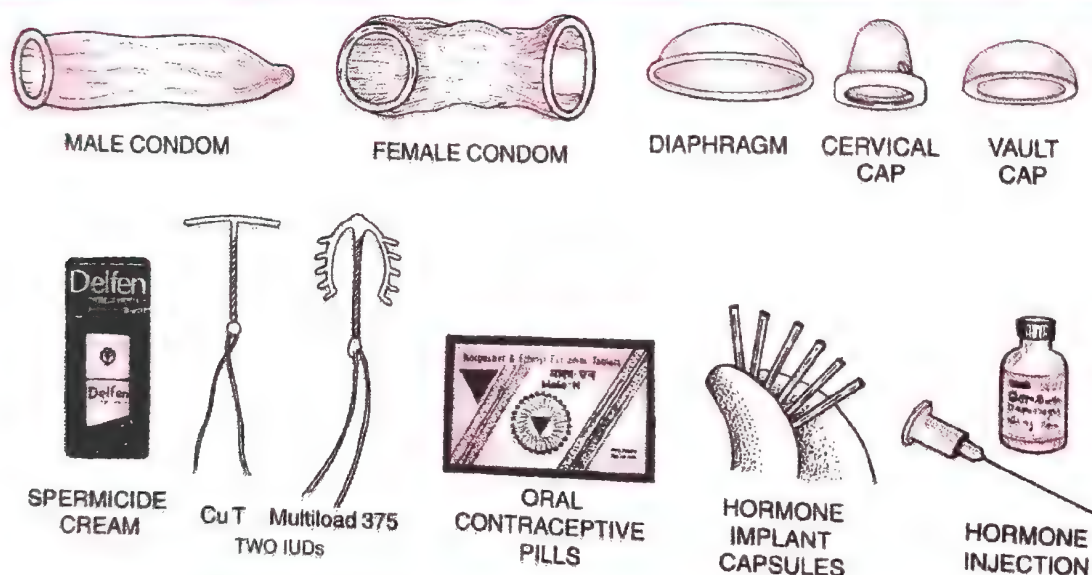


Fig. 4.2. Some commonly used contraceptive devices.

3. Chemical Methods (Spermicides). Foam tablets, creams, jellies and pastes are inserted in the vagina before intercourse to prevent sperms from entering the uterus. These contain spermicides (*kill spermatozoa*) such as lactic acid, citric acid, boric acid, zinc sulphate and potassium permanganate. **Sponge** ('Today') is a foam suppository or tablets containing nonoxynol as spermicide. **Delfin** is also available in the form of cream. They can be used by anyone who is not allergic to these spermicides. These are relatively unreliable.

4. Intrauterine Devices (IUDs). These devices are effective and popular methods. IUDs are inserted by doctors or expert nurses in the uterus through vagina. These devices are presently available as the **non-medicated IUDs** (e.g., Lippes loop), **copper releasing IUDs** (CuT, Cu7, Multiload 375) and the **hormone releasing IUDs** (Progestasert, LNG-20). IUDs increase phagocytosis of sperms within the uterus and the Cu ions released suppress sperm motility and the fertilising capacity of sperms. The hormone releasing IUDs, make the uterus unsuitable for implantation and the cervix hostile to the sperms. IUDs are ideal contraceptive methods used by the females. In India, it is one of most widely accepted

Some drawbacks of IUCDs (also called IUDs = Intrauterine Devices) are :

- (i) Their presence may act as a minor irritant and this makes the egg to move down the oviducts (Fallopian tube) and uterus before fertilization or implantation.
- (ii) Their spontaneous expulsion, even without the woman's knowledge.
- (iii) They can cause excess menstrual bleeding and pain.
- (iv) Risk of perforation of uterus.
- (v) Tubal pregnancy in plantation of embryo in the oviduct (Fallopian tube).
- (vi) Risk of infection.

This device is not recommended for those who eventually intend to conceive.

5. Oral Contraceptive Pills (Oral Pills). They are used in the form of tablets, therefore, they are called 'pills'. Pills have to be taken daily for 21 days starting within the first five days of menstrual cycle. After a gap of 7 days (during which menstruation occurs) it has to be repeated. They inhibit ovulation and implantation. Pills are very effective with lesser side effects.

Hormonal pills act in four ways.

- (i) Inhibition of ovulation.
- (ii) Inhibition of motility and secretory activity of oviducts (Fallopian tubes).
- (iii) Changes in cervical mucus impairing its ability to allow passage and transport of sperms.
- (iv) Alteration in uterine endometrium to make it unsuitable for implantation.

Types of Oral Contraceptive Pills. They contain either **progestin** (= progestogen = progesterone) alone or a combination of progestogen and oestrogen (= estrogen).

Thus oral contraceptive pills are of two types : mini pills and combined pills.

(i) **Mini Pills.** They contain progestin only (with no oestrogen) "**Saheli**" contains a non-steroidal preparation called **centchroman** which is taken once in a week after an initial intake of twice a week dose for 3 months. It has high contraceptive value with very little side effects. *Saheli contraceptive pill has been developed at Central Drug Research Institute (CDRI), Lucknow.*

(ii) **Combined Pills.** They are most commonly used oral contraceptive pills. They contain synthetic progesterone and oestrogen to check ovulation. Pill **Mala D** and **Mala N** are commonly used combined contraceptive pill. They are taken daily without break.

Oral contraceptive pills increase the risk of intravascular clotting. Therefore, they are not recommended for women with a history of disorders of blood clotting, cerebral blood vessel damage, hypertension, liver malfunction, heart disease, or cancer of the breast or reproductive system.

6. Subcutaneous Implants (Norplant). A new contraception is a *subcutaneous* ('under the skin') *implantation* of synthetic progesterone. It acts similarly to oral contraceptives by blocking ovulation and thickening the cervical mucus to prevent sperm transport. The new contraceptive, once implanted, is effective for five years. Six matchstick-sized capsules containing the steroid are inserted under the skin of the inner arm above the elbow. The capsules slowly release the synthetic progesterone for about five years.

It is very safe, convenient, and effective, and long-lasting (5 years). The woman has irregular periods or periods may be absent. Minor surgical procedure is needed for insertion and removal.

7. Hormone Injections (Depo-Provera). These are progesterone-derivative injections.

Injection is given once every 3 months, that releases a hormone slowly and prevents ovulation. They are convenient and highly effective with no serious side effects. There is occasional heavy menstrual bleeding.

8. **Morning After Pills.** Implantation can also be checked by so-called **morning after pills**, also known as **emergency contraceptive**. The first term is actually a misnomer, because these pills can prevent pregnancy if taken within 72 hours of coitus (copulation), not just the morning after unprotected sexual intercourse. The most common form of emergency contraceptive is a kit consisting of a high dose of birth control pills. They can either suppress ovulation or prevent. These kits are for emergency use only, for instance, if a condom breaks or in the case of rape, i-pill, PILL 72 and UNWANTED 72 are commonly used. They are more effective in first 24 hours. Their side effects are menstrual irregularity, breakthrough bleeding from the uterus, vomiting, etc. Therefore, they should not be used as a substitute for ongoing contraceptive methods.

(B) Termination or Permanent Methods of Birth Control

Sterilisation (Surgical Methods). These methods prevent pregnancy. Surgical methods block gamete transport and hence prevent fertilization. Sterilisation procedure in the male

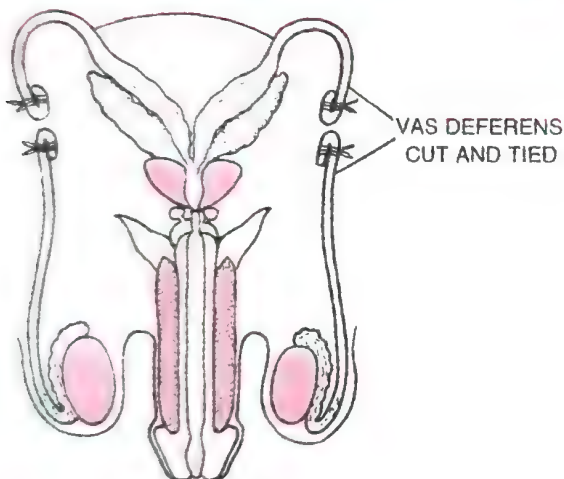


Fig. 4.3. Vasectomy.

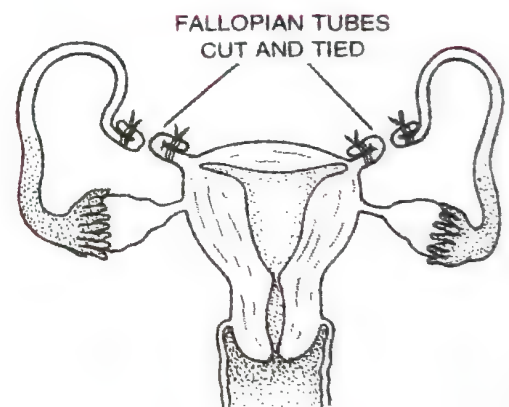


Fig. 4.4. Tubectomy.

is termed **vasectomy** and that of the female **tubectomy** (**tubal ligation**). In vasectomy a small part of the vas deferens is removed or tied up through a small cut on the scrotum while in tubectomy a small part of the Fallopian tube is removed or tied up through a small cut in the abdomen or through vagina. Both vasectomy and tubectomy are very effective but reversibility is very poor.

It is essential to mention here that the selection of a suitable contraceptive method should be practiced in consultation with qualified doctors. One must remember that contraceptives are not regular requirements for keeping good reproductive health. Because they are against natural conception/pregnancy. In spite of that one has to use them to prevent pregnancy. Although



Fig. 4.5. Tying a Fallopian Tube by laproscopic procedure.

contraceptives have a significant role in checking uncontrolled growth of population yet their possible ill effects like nausea (an inclination to vomit), abdominal pain, breakthrough bleeding, irregular menstrual bleeding or even breast cancer.

Differences between Vasectomy and Tubectomy

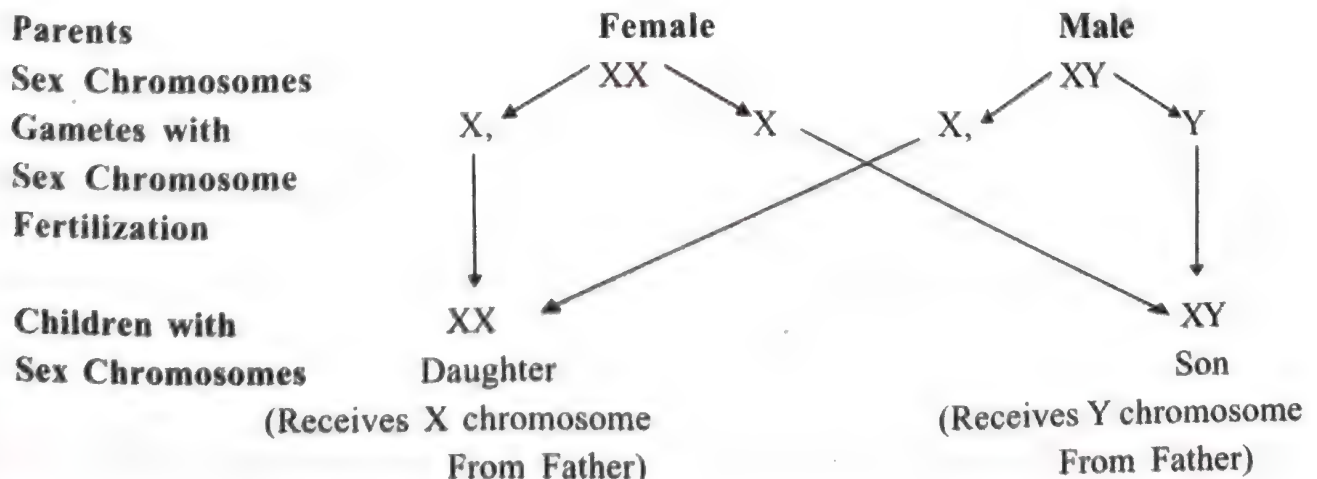
<i>Vasectomy</i> (vas = vas deferens, <i>ektome</i> = cutting)	<i>Tubectomy</i> (<i>tubus</i> -pipe, <i>ektome</i> -cutting)
1. It is a sterilization technique for the males.	1. It is a sterilization technique for the females.
2. The two vasa deferentia are cut and tied up.	2. The two oviducts are cut and tied up.
3. Passage of sperms is prevented.	3. Passage of ova is prevented.

Average Failure Rate of Various Contraceptive Techniques

Contraceptive method	Average Failure rate (Annual pregnancies/100 women)
None	90
Natural methods	20-30
Coitus interruptus	23
Chemical contraceptives	20
Barrier methods	10-15
Oral contraceptives	2-2.5
Intrauterine contraceptive device	4
Implanted contraceptive	1

INEQUALITY OF SEXES

Human female produces similar eggs (ova), each with X chromosomes. However, human male produces two types of sperms ; 50% sperms have X chromosomes and 50% sperms possess Y chromosomes. The sex of the newly born child is solely determined by the type of sperm that fertilises the egg (ovum). If the egg is fertilised by an X-bearing sperm a girl is produced. If the egg (ovum) is fertilised by a Y-bearing sperm, a boy is produced. Which type of sperm fuses with the egg is purely a chance. *Thus it is the father who is biologically responsible for the sex of the child.* Unfortunately, it is the mother who is always blamed for giving birth to female child.



Women plays a very important role in the continuity of the family and human species. She nourishes the foetus in her womb for nine months and after birth she nourishes the infant until the child learns to feed herself/himself. Hence *biologically woman is superior to man*. However, women are a victim of social injustice, and are treated inferior to man. But an educated person who has understood the scientific basis of sex determination, should be rational and objective and free from prejudice in matters pertaining to the equality of sex. In fact man should feel obliged to woman because she plays a significant role in the continuity of the family and human race.

Medical Termination of Pregnancy (MTP)

Meaning. Medical termination of pregnancy or abortion is the termination of pregnancy before the foetus becomes viable. Government of India legalised MTP in 1971.

Period. MTP is comparatively safe upto 12 weeks (the first trimester) of pregnancy. It becomes more risky after the first trimester period of pregnancy as the foetus becomes intimately associated with the maternal tissues.

Incidence. About 45 to 50 million MTPs are done in a year all over the world which is 1/5th of the total number of pregnancies in a year.

Types

(i) **Spontaneous.** Probably, one-third of all pregnancies abort spontaneously within four weeks of conception. In many cases the woman never knows that she has been pregnant, and the abortion passes unrecognised with the menses.

(ii) **Therapeutic.** A pregnancy can be legally terminated in its early stages if doctors advise that its continuation would seriously affect the health of the mother. At present, termination is legally allowed up to 28th week of pregnancy if the family physician and the gynaecologist consider the need for abortion.

Why MTPs ? The answer is to get rid of unwanted pregnancies due to (i) casual unprotected intercourse; (ii) do not use contraceptive during coitus; and (iii) MTPs are also necessary where pregnancy can be harmful or even fatal to the mother or to the foetus or both.

Significance. (i) It helps in getting rid of unwanted pregnancies and such pregnancies which may be harmful or even fatal either to the mother or to the foetus of both. (ii) MTP plays a significant role in decreasing the human population.

Drawbacks. (i) It is being misused to abort even the normal female foetuses. (ii) Majority of MTPs are performed illegally by unqualified quacks which may be fatal. (iii) It has raised many emotional, ethical, religious and social issues.

Sexually Transmitted Diseases (STDs)

Definition. Diseases or infections which are transmitted through sexual intercourse with infected persons are collectively called **sexually transmitted diseases (STDs)** or **Venereal diseases (VD)** or **reproductive tract infections (RTI)**.

Causing Agents (Pathogens). STDs are usually caused by (1) Bacteria (2) Viruses (3) Chlamydiae (4) Protozoa (5) Nematodes (6) Ectoparasites and (6) Fungi.

Mode of Transmission. STDs are transmitted by

(i) sexual intercourse with infected persons, (ii) sharing of injection needles, surgical instruments, etc., and (iii) transfusion of blood from an infected mother to the foetus.

Cure for STDs. Except HIV infection, Hepatitis-B and genital herpes all other STDs are completely curable if detected early and treated properly.

Common Symptoms. Early symptoms of most of these diseases are itching, fluid discharge, swelling, slight pain etc.

Consequences of Delayed Treatment. If proper and timely treatment is not given STD may lead to complications such as pelvic inflammatory diseases (PID), abortions, still birth, ectopic pregnancies, infertility or even cancer of reproductive tract.

Efforts of Government. STDs are a major threat to healthy society. Incidence of STDs is very high in persons who have 15-24 year of age. Government of India has initiated special reproductive health care programmes to prevent the early occurrence, early detection and cure of these diseases.

Prevention. For prevention following simple principles should be followed :

- (i) Avoid sex with unknown partner/multiple partners.
- (ii) One should always use condoms during intercourse.
- (iii) If a person is in doubt he/she must consult a qualified doctor. If STD is detected one should get complete treatment.

Confirmatory Tests for Sexually Transmitted Diseases. These include:

- (i) Culture and microscopic observation with specific staining.
- (ii) Detection of specific antigen/antibody using Enzyme Linked Immunosorbent Assay (ELISA) like technique.
- (iii) DNA hybridisation.
- (iv) Polymerase chain reaction (PCR)

Types. Following types of STDs are present

1. STDs caused by Bacteria

- (i) **Syphilis. Pathogen.** *Treponema pallidum*

Symptoms. (i) In the **first stage** there is indurated infectious and painless ulcer or chancre on the genitals and swelling of local lymph glands. Chancre is the initial lesion of syphilis commonly a more or less distinct ulcer or sore with hard base. (ii) In the **second stage**, chancre is healed and there are skin lesions, rashes, hair loss, swollen joints and flu-like illness occasionally. (iii) In the **tertiary stage** chronic ulcers appear on palate, nose and lower leg. There can be paralysis, brain damage, blindness, heart trouble and aortic impairment. (iv) In the **latent syphilis**, there is no evidence of the disease.

Diagnosis. The disease is diagnosed by clinical symptoms, microscopic examination and antibody detection, e.g., VDRL (Venereal Disease Research Laboratory), ELISA test.

Transmission. It is through sexual contact and from mother to children.

Incubation period. 10–90 days.

Treatment. It is curable through appropriate antibiotics, e.g., Penicillin, tetracycline.

- (ii) **Gonorrhoea. Pathogen.** *Neisseria gonorrhoeae*

Symptoms. The bacterium lives in genital tubes, produces pus-containing discharge, pain around genitalia and burning sensation during urination. It may lead to arthritis and eye infection in children of gonorrhoea afflicted mothers.

*Infact it is Spirochaete.

Diagnosis. It is carried out by clinical symptoms, Gram staining of discharge and culture.

Transmission. It is spread through sexual contact, common toilets and under clothes.

Incubation period. 2–5 days.

Treatment. Disease can be cured through use of appropriate antibiotics, e.g., Penicillin, Ampicillin.

(iii) **Chancroid. Pathogen.** *Haemophilus ducreyi*.

Symptoms. Ulcer appears at the site of infection generally over external genitalia. It is painful and bleeds easily. Nearby lymph nodes swell up and become tender.

Diagnosis. The disease is diagnosed by clinical symptoms, staining of discharge and cell culture.

Transmission. It is spread through sexual contact.

Treatment. Effective antibiotics are ceftriaxone, erythromycin, ciprofloxacin and trimethoprim-sulphamethoxazole.

2. STDs caused by Viruses.

(i) **AIDS. Pathogen.** *Human Immunodeficiency Virus (HIV)*

Symptoms. The symptoms of AIDS include fever, lethargy, pharyngitis, weight loss, nausea, headache, rashes, etc. Because HIV attacks helper T lymphocytes, the patient gets immune deficiency and he/she is unable to protect himself/herself against infections.

Diagnosis. AIDS can be diagnosed by **ELISA** test and **Western Blotting** test. Western Blotting test is used for confirmation of ELISA positive cases. PCR is also used to diagnose AIDS.

Transmission. Virus of AIDS is transmitted via blood and semen.

Incubation period. 6 months to 10 years.

Treatment. Although there is no cure of AIDS, yet use of certain drugs can prolong the life of AIDS patient. **Zidovudine** or **Azidothymidine (AZT)** is the drug of choice for the treatment of AIDS. **Didanosine** is another drug employed to treat AIDS.

(ii) **Hepatitis B. Pathogen.** *Hepatitis B Virus (HBV)*

Symptoms. Its symptoms include fatigue, jaundice (yellowing skin), persistent low grade fever, rash and abdominal pain. It can cause cirrhosis and possibly liver cancer.

Diagnosis. Hepatitis-B can be diagnosed by Australian antigen test which is now also called **Hepatitis-B surface antigen (HBsAg)**. It is also diagnosed by **ELISA**.

Transmission. Mode of transmission may be blood transfusion, sexual contact, saliva, tears, intravenous drug abuse, tattooing, ear and nose piercing, sharing of razors.

Incubation period. 30–80 days.

Treatment. It is incurable STD.

Vaccines produced through recombinant DNA technology are available to prevent hepatitis B infection.

(iii) Hepatitis C is also STD caused by HCV (Hepatitis-C Virus). It is also diagnosed by **ELISA**.

(iv) **Genital Herpes. Pathogen.** *Herpes simplex virus*

Symptoms. There are vesiculopustular lesions followed by clusters of painful erythematous ulcers over external genitalia and peri-anal regions. Symptoms are more severe in

females. Infection of neonate can occur in case of infected females. There is fever, headache pain, itching, vaginal and urethral discharge, with tender inguinal lymphadenopathy (swelling of lymph nodes). Urethral and cervix infections also occur.

Diagnosis. Detection is carried out by clinical symptoms, antigen detection, PCR and nucleic acid hybridisation.

Transmission. The disease is primarily transmitted sexually through genital secretions but also contact with viroids and genitalia.

Treatment. It is also incurable STD.

(v) **Genital Warts. Pathogen.** *Human papilloma virus* (HPV)

Symptoms. Warts (benign, hard outgrowths with horny surface) develop over the skin and mucosal surface of external genitalia and perianal area. In women infection may enter vagina and cervix.

Diagnosis. Diagnosis is made through clinical symptoms, antibody detection, culture and DNA hybridisation.

Transmission. It spreads through sexual intercourse with carriers of the viruses of this disease.

Treatment. Treatment requires special skill especially in case of internal warts. Cryosurgery is used in removal of warts. Podophyllum preparations are useful. The dried rhizome and roots of *Podophyllum peltatum* are called *Podophyllum* preparations.

3. STDs caused by Chlamydia

Chlamydiasis. Pathogen. *Chlamydia trachomatis* of DEFGHIJK serotypes.

Symptoms. *Chlamydia trachomatis* is a human pathogen that causes trachoma, sexually transmitted and perinatal infection. *Chlamydia* is obligate intracellular pathogen. It causes urethritis epididymitis (with unilateral scrotal pain, tenderness and swelling), mucopurulent (with yellowish mucus and pus), cervicitis, inflammation of Fallopian tubes, proctitis (rectal pain with mucus and occasional bleeding).

Diagnosis. Detection techniques are clinical. Gram-staining of discharge, antigen detection and nucleic acid hybridisation.

Transmission. It spreads by sexual contact with the infected mating partner.

Incubation Period. About one week.

Treatment. Antibiotics like **tetracycline**, **erythromycin** and **rifampacin** are effective but penicillin is not effective in chlamydiasis.

Some Important STDs and Common Techniques for their Detection

STD	Causal agent	Detection Techniques
1. Chlamydiasis	<i>Chlamydia trachomatis</i>	Clinical, Gram-staining of discharge, antigen detection, nucleic acid hybridisation.
2. Gonorrhoea	<i>Neisseria gonorrhoeae</i>	Gram-staining of discharge, culture
3. Trichomoniasis	<i>Trichomonas vaginalis</i>	Microscopic examination, culture
4. Genital Herpes	<i>Herpes simplex virus</i>	Clinical, antigen test, PCR
5. Syphilis	<i>Trepanema pallidum</i>	Antibody detection, e.g., VDRL, ELISA test.
6. Chancroid	<i>Haemophilus ducreyi</i>	Clinical, culture

7. Genital warts	<i>Human papilloma virus (HPV)</i>	Clinical, antibody detection, culture, DNA hybridisation
8. Hepatitis B	<i>Hepatitis B Virus</i>	ELISA
9. Hepatitis C	<i>Hepatitis C virus</i>	ELISA
10. AIDS	<i>Human immunodeficiency Virus (HIV)</i>	ELISA, PCR
11. Enterobiasis	<i>Enterobius vermicularis</i>	Microscopic examination

4. STDs caused by Protozoa.

(i) Trichomoniasis. Pathogen. *Trichomonas vaginalis*

Symptoms. The parasite infects both males and females. In females it causes vaginitis with foul smelling, yellow vaginal discharge and burning sensation. In males it causes urethritis, epididymitis and prostatitis resulting in pain and burning sensation.

Transmission. Through sexual intercourse.

Diagnosis. Diagnosis is made by clinical symptoms, microscopic examination, culture and immunofluorescent antibody staining.

Treatment. Standard treatment is metronidazole but partners be treated simultaneously.

(ii) Amoebiasis. Pathogen. *Entamoeba histolytica* — it lives in large intestine of human beings.

Symptoms. The patient passes blood along with the faeces and feels pain in the abdomen.

Transmission. Its infection is normally via contaminated food but sometimes, it is transmitted through sexual contact.

Treatment. Antiamoebic tablets are given to the patient.

(iii) Giardiasis. Pathogen. *Giardia lamblia*

Symptoms. It lives in human intestine. The parasites interfere with digestion and absorption of food. This parasite causes epigastric pain, abdominal discomfort, diarrhoea, headache and sometimes fever.

Transmission. Normally the infection of the parasites is through contaminated food but sometimes this parasite is transmitted through sexual contact.

Treatment. Antiamoebic tablets are recommended.

5. STDs caused by Nematode

Enterobiasis Pathogen. *Enterobius vermicularis* (pinworm)

Symptoms. The parasite causes intense itching of the anus, inflammation of mucous membrane of colon and appendix, nausea, abdominal pain and diarrhoea.

Transmission. The patient scratches the affected area. The eggs easily get under the finger nails from where they may get into the mouth. The infection is also through sexual contact.

Treatment. Anthelmintic tablets are recommended.

6. STDs caused by Arthropods (Ectoparasites)

(i) Scabies. Pathogen. *Sarcoptes scabiei*

Symptoms. Intense itching and patches on the skin.

Transmission. Mite spreads the parasite.

(ii) **Pediculosis. Pathogen.** *Phthirus pubis* (Pubic Louse)

Symptoms. Painful itching and red patches on the skin of pubic region are found.

Transmission. The female lice lay eggs near the base of pubic hair and the young hatch within a few days to expand the infestation. The lice are passed by sexual contact or by sharing clothes, bed sheets or blankets.

Treatment. Medicated shampoos are recommended.

7. STD caused by Yeast (Fungus)

Candidiasis. Pathogen : *Candida albicans* (vaginal yeast).

Symptoms. This yeast is normally found in the mouth, colon and vagina. Women with yeast infections experience painful inflammation of the vagina often with a thick, cheesy discharge. Man may develop a painful inflammation of the urethra through sexual contact with an infected woman.

Transmission. The parasite spreads through sexual contact.

Treatment. It involves the use of antibiotics such as clotrimazole, miconazole and nystatin.

Infertility

Definition. Infertility is a failure to conceive within one or more years of regular unprotected coitus (copulation).

Types of Infertility. It is of two types.

(i) **Primary infertility.** It denotes those patients who have never conceived.

(ii) **Secondary infertility.** It indicates previous pregnancy but failure to conceive subsequently.

Infertility is caused by defects in the male or in the female or in both.

Infertility in Males

1. **Cryptorchidism** — it is a condition in which testes are unable to descend in scrotal sacs so that sperms are not produced— azospermia.

2. **Alcoholism** causes defective spermatogenesis.

3. **Thyroid dysfunction.**

4. **Impotency**— male is unable to erect and penetrate the penis into the vagina of the female.

5. **Gonadotrophin (LH, FSH) deficiency.**

6. Use of antihypertensive and antipsychotic **drugs** for a long time.

7. **Immotile cilia** — sperms are unable to move from vagina to the upper portion of the genital tract of the female.

8. **Y-chromosome deletions.**

9. Absence or blockage of vasa deferentia and vasa efferentia.

10. **Acquired infection** like mumps, infection of seminal vesicle and prostate cause oligospermia (poor sperm count).

11. Most common variety of **antisperm antibodies** are IgG, IgM and IgA. IgG may be found in cervical mucous serum and semen.

12. Failure to deposit sperm high in the vagina (**coital problems**).
13. The scrotal temperature is raised in varicocela (collection of dilated veins) causing oligospermia.
14. **ADAM** (Androgen deficiency in ageing males) also called male menopause.
15. **Low fructose** content and high prostaglandin content in the seminal fluid.
16. **Vasectomy**.

Infertility in Females

1. **Anovulation** (no ovulation). There is no corpus luteum formation. There is oligoovulation (deficient ovulation).
2. There is **luteal phase defect** (LPD)— drug induced ovulation, decreased level of FSH and/or LH.
3. **Defective growth of uterus and vagina**.
4. Uterine factor includes unfavourable endometrium for implantation— **chronic endometritis** (TB), **fibroid uterus**, etc.
5. Cervical factor includes **ineffective sperm penetration**— chronic cervicitis, presence of antisperm antibody, elongation of cervix.
6. **Fimbriae** of the Fallopian tube may not pick up secondary oocyte from the ovary.
7. **Dyspareunia** (painful sexual intercourse experienced by a woman).
8. Increased sperm **phagocytosis** by macrophages.
9. **Fertilization and implantation failure**.
10. **Early miscarriage**.
11. **Ectopic Pregnancy**.
12. **Tubectomy**.

Lack of knowledge of timing of coitus to utilize the fertile period by both the male and female is also important cause of infertility.

Treatment

Specialized infertility clinics can help in proper treatment of some of these disorders and enable these couples to have children. In male use of vitamin E, C, folic acid and B₁₂ improve oligospermia. Clomiphene citrate intake (25–50 mg daily for 25 days a month for three months) improves production of gonadotropins and stimulates secretion of testosterone. Testosterone may be taken orally (100–160 mg daily for 3–4 months). Dexamethasone is used to correct the presence of antisperm antibodies in the semen. Erectile dysfunction is corrected by use of sildenafil surgery required for obstruction of vasa efferentia and vasa deferentia and also for correcting varicocele and nondescent of testes. Male infertility may be corrected by avoidance of intake of alcohol and avoidance of light and warm undergarments.

In females dexamethasone is used to correct antisperm antibodies in cervical mucus. Antibiotics are used for treating infection. Ovulation is induced by clomiphene citrate. Ovarian cysts, Fallopian tube blockage and uterine defects are corrected by surgery.

However, where such treatment is not possible, the couples can be assisted to have children through certain special techniques called the **assisted reproductive technologies** (ART).

Assisted Reproductive Technologies (ART)

These are the applications of Reproductive Technology to solve infertility problems. Some important techniques are as follows.

1. Test Tube Baby
2. Artificial insemination technique (AIT)
3. Gamete intra Fallopian transfer (GIFT)
4. Intracytoplasmic sperm injection (ICSI)

1. **Test Tube Baby.** The fusion of ovum and sperm is done outside the body of woman, to form a zygote which is allowed to divide to form embryo. This embryo is then implanted in uterus where it develops into a foetus which in turn develops into a child. This is called test tube baby. In this method, ova from the wife/donor female and sperms from the husband/donor male are induced to form zygote in the laboratory. The zygote is allowed to divide forming 8 blastomeres. The zygote or early embryo is transferred into the Fallopian tube (**ZIFT—Zygote Intra Fallopian Transfer**). If the embryo is with more than 8 blastomeres it is transferred into the uterus (**IUT – Intra Uterine Transfer**) to complete its further development. Thus this is **in vitro fertilization (IVF – fertilisation outside the body in almost similar conditions as that in the body)** followed by embryo transfer (**ET**). Embryo formed by **in vivo fertilization** (fusion of gametes within the female) can also be used for such transfer.

Success Rate. Implantation of embryo takes place in the uterus where it develops into a foetus which forms a child. The mother will give birth to a normal child on the completion of gestation. This is test tube baby. It is to be noted that the baby is not reared in the test tube. The success rate of this technique of producing test tube babies is less than 20%.

First Test Tube Baby. The first test tube baby **Louise Joy Brown**, was born to Lesley and Gilbert Brown on July 25, 1978, in Oldham, Lancashire, England with the help of **Dr. Patrick Steptoe** and **Dr. Robert Edwards**. Dr Robert Edwards got 2010 Nobel Prize for developing a technique for production of test tube baby. Later on test tube babies were also born in other countries. India's first test tube baby was born on August 6, 1986 at K.E.M Hospital, Mumbai. Her name is **Kum Harsha**. The credit for India's first test tube baby goes to **Dr Indra Hinduja**. Some persons claimed that India's (Asia's) first and world's only second test tube baby was born in Kolkata on 3 October 1978. Previously, her name was **Durga** (now her name is Kanupriya Agarwal). The man behind this pioneering effort was **Dr Subhas Mukherjee**.

2. **Artificial Insemination (AI).** In artificial insemination (AI) technique, the sperms collected either from the husband or a healthy donor are artificially introduced either into the vagina or into the uterus (**IUI—Intra-uterine insemination**) of the female. It is done in infertility cases either due to inability of male partner to copulate the female or due to very low sperms count in the semen of the male partner.

Just near the time of ovulation, about 0.3 ml of washed and concentrated semen having atleast 1 million sperms from husband is introduced artificially through a flexible polyethylene catheter into the vagina or into uterus called intra-uterine insemination or (**IUI**). Washing in culture media removes the proteins and prostaglandins from semen. Best results are obtained when the motile sperm count is more than 10 million. The fertilising capacity of spermatozoa (sperms) is for 24–48 hours. The procedure may be repeated 2–3 times over a period of 2–3 days.

The result varies in different centres, ranging 20–40 per cent. IUI alongwith super ovulation gives higher.

When husband sperms are defective, AID (Artificial Insemination Donor) method is used. In this method semen is taken from semen bank.

3. **Gamete Intra Fallopian Transfer (GIFT).** GIFT was first described by Asch and colleagues in 1984. It is a more expensive and invasive procedure than IVF (*in vitro* Fertilization) but its results are better than IVF. In this technique, both the sperm and unfertilised oocytes are transferred into the Fallopian tubes. Fertilization is then taking place *in vivo* (inside the body of the female).

For GIFT technique normal Fallopian tubes are required. The indications are the same as in IVF except the tubal factor. Best result is obtained in unexplained infertility but the result is poor in male factor abnormality. In this procedure the superovulation is done as in IVF. Two collected oocytes alongwith about 200,000–500,000 motile sperms for each Fallopian tube are placed in a plastic tube container. It is then transferred through laproscope and inserted 4 cm into the distal end of the Fallopian tube where the combination is injected. The overall success rate through this procedure is 27–30 per cent.

4. **Intra Cytoplasmic Sperm Injection (ICSI).** It was first described by Van Steirteghem and colleagues in 1992 in Belgium. The following conditions cause infertility.

Severe oligospermia, obstruction of efferent duct system in male, presence of sperm antibodies, congenital absence of both vasa efferentia and vasa deferentia in male, failure of fertilization in IVF, hardened zona pellucida unexplained infertility, etc.

In this procedure first sperms are obtained through ejaculation. Sperms can be recovered by TESE (Testicular sperm extraction) or by MESA (microsurgical epididymal sperm aspiration) techniques.

In this technique one single spermatozoon or even a spermatid is injected directly into the cytoplasm of an oocyte by micropuncture of the zona pollucida. This procedure is done under a high quality inverted operating microscope. Micropipette is used to hold the oocyte while the spermatozoon is injected inside the cytoplasm of the oocyte (ooplasm) by an injecting pipette.

ICSI is very effective as compared to other micromanipulation techniques like SUZI (subzonal insemination). ICSI is very effective to reduce the need of AID. The fertilization rate through ICSI is about 60–70 per cent. However, pregnancy rate through this procedure is 20–40 per cent.

Zygote Intra-Fallopian Transfer (ZIFT). In this technique zygote or early embryo (with upto 8 blastomeres) is transferred into the Fallopian tube.

Intra Uterine Transfer (IUT). If the embryo is with more than 8 blastomeres, it is transferred from the laboratory to the uterus to complete its further development.

All these methods require extremely high specialised persons and expensive instruments. Therefore, there are only few such centres in the country and hence their benefits are obtained only by limited persons. Emotional, social and religious factors interfere in the adoption of these methods. In India there are so many orphaned and destitute (without food, clothes and other necessary things) children. Adoption of these children is one of the best methods for couples looking for parenthood. Our laws also permit legal adoption.

Surrogate Mother. A developing embryo is implanted in the uterus of another female. A woman who substitutes or takes the palce of the real mother to nurse the embryo is called **surrogate mother**. Embryo transplants are more useful in animals than in humans.

Detection of Foetal Disorders during Early Pregnancy

1. **Amniocentesis.** It has already been described in the beginning of this Chapter.
2. **Chorionic Villi Sampling (CVS).** In this technique the physician inserts a narrow, flexible tube through the mother's vagina and cervix into the uterus (guided by ultrasound) and withdraws a small amount of foetal tissue (chorionic villi) from the placenta. Because the cells of the chorionic villi are undergoing rapid mitosis, these cells can be used for karyotyping. Results of the karyotyping, along with some biochemical tests, are available within a few hours. The speed of CVS is an advantage over amniocentesis. Another advantage is that CVS can be performed early, between the eighth and tenth weeks of pregnancy. CVS is less widely available than amniocentesis. Since the CVS procedure is **invasive**, it carries with it an inherent risk to both foetus and mother. This test should, however, be done for the pregnant women over the age of 35 because of the enhanced risk of Down's syndrome.
3. **Noninvasive Techniques.** These techniques are available to determine the foetal condition. One of these is the **ultrasound imaging**. Another technique is based on the fact that a few foetal blood cells leak across the placenta into the mother's blood stream. A blood sample from the mother provides enough foetal cells that can be tested for genetic disorders.
4. **Foetoscopy.** It is another technique in which a needle-thin tube containing a viewing-scope is inserted into the uterus, giving the physician a direct view of the foetus.

ADDITIONAL INFORMATION

- Fecundity is **potential capability** of an organism to produce reproductive units such as eggs, sperms or asexual structures.
- **Vitamin E** maintains normal functioning of reproductive organs hence Vitamin E is also called antiserility vitamin.
- **Manganese** is important for normal reproduction. Its deficiency causes infertility.
- **Thymosin** hormone of Thymus gland also hastens attainment of sexual maturity.
- **Adolf Butenandt** (1929, 1931) discovered sex hormones. He got the 1939 Nobel Prize (chemistry) jointly with Leopold Ruzicka.
- **Baldness** is related to male sex hormones
- **World Health Organisation (WHO)** set up in Geneva (Switzerland) on 7 April 1948 with the aim of attaining highest possible level of health for all people.
- The five billionth baby was born on July 11, 1997. Therefore, 11th July is observed as **World Population Day**.
- **Baruch Blumberg** (1925) succeeded in preparing a vaccine against Hepatitis-B. Blumberg was awarded the Nobel Prize in 1976 along with Gajdusek who did similar work.
- Govt. of India enforced the **Pre-natal Diagnostic Techniques (Regulation and Prevention of Misuse) Act., 1994**, since January 1, 1994 under which all genetic counselling centres and laboratories are required to apply for registration.
- **December 1— World AIDS Day**
- **NACO** (National AIDS Control Organisation) was established in 1992.
- Destruction of foetus in the uterus is called **foeticide**.
- Industrialist J.R.D Tata received the "1992 United Nations Population Award" for his crusade to stabilise India's population growth.
- Due to side effect of increased secretion of sex hormones the skin-pores are clogged giving rise to **acne/pimples**.
- **DMPA**, Depot medroxyprogesterone acetate and **NET-EN-** Nor-ethiosterone enantate; are two injectable hormonal contraceptives.
- **POST.** Peritoneal Oocyte and Sperm Transfer

- SUZI. Subzonal Insemination
- TESE. Testicular Sperm Extraction
- NACO. National AIDS Control Organisation
- DPMA. Depot-Medroxy Progesterone acetate
- NETEN. Northisterone enanteta
- AID. Artificial insemination donor
- RCH—Reproductive and Child Healthcare.
- NGOs—Non Government Organizations

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. What do you think is the significance of reproductive health in a society ?
 ✓ Reproductive health in a society is significant because the people are aware of (i) birth control methods and advantages of small family, (ii) sexually transmitted diseases and methods to avoid them, (iii) importance of breast feeding and post natal care of the mother and baby and (iv) equal opportunities for the male and female children.
2. Suggest the aspects of reproductive health which need to be given special attention in the present scenario.
 (PSEB 2009)
 ✓ (i) Problems due to uncontrolled population growth. (ii) Social evils like sex-abuse and sex-related crimes. (iii) Safe and hygienic sexual practices. (iv) Sexually transmitted diseases. (v) Care of pregnant mother. (vi) Postnatal care of mother and child.
3. Is sex education necessary in schools ? Why ?
 (PSEB 2009)
 ✓ Sex education is necessary in schools. It gives (i) right information and avoids myths and misconceptions about sex-related aspects, (ii) proper information about reproductive organs, adolescence and its related changes, (iii) information about safe and hygienic sexual practices, (iv) Sexually transmitted diseases.
4. Do you think that reproductive health in our country has improved in the past 50 years ? If yes, mention some such areas of improvement.
 (PSEB 2009)
 ✓ Yes, in the last 50 years, reproductive health in our country has improved. Some such areas of improvement are (i) massive child immunization (ii) maternity and child health (iii) increasing use of contraceptives (iv) family planning.
5. What are the suggested reasons for population explosion ?
 ✓ (i) Decline in Death Rate (ii) Decline in Maternal Mortality Rate (iii) Decline in Infant Mortality Rate (IMR) (iv) Increase in the number of people in the reproductive age (v) Advancement in technology avoids hunger deaths.
6. Is the use of contraceptive justified ? Give reasons.
 ✓ Use of contraceptive is justified. The population growth at this rate would lead to an absolute scarcity of basic requirements like food, shelter, clothing, etc. There will be an increase in STDs (including AIDS).
7. Removal of gonads cannot be considered as a contraceptive option why ?
 ✓ An ideal contraceptive should be effective as well as reversible. Once the gonads are removed, they cannot be replaced when necessary. Hence removal of gonads cannot be considered as a method of contraceptive.
8. Amniocentesis for sex determination is banned in our country. Is this ban necessary ? Comment.
 ✓ Since it is misused to find out the sex of the foetus leading to female foeticides, it is necessary. **Amniocentesis** is the prenatal diagnostic technique, that helps to find out chromosomal (genetic) disorders, metabolic disorders of the foetus ; in extreme cases where the foetus is found to be suffering from an incurable disorder MTP is advised. By banning this, the advantage of preventing an unwanted birth is lost.
9. Suggest some methods to assist infertile couples to have children.
 ✓ (i) Test tube babies (ii) Gamete intra fallopian transfer (GIFT) (iii) Intra cytoplasmic sperm injection (ICSI) (iv) Artificial insemination technique (AIT).
10. What are the measures one has to take to prevent from contracting STDs ?
 ✓ STDs can be prevented by (i) Avoiding sex with unknown partner or multiple partners (ii) Using condoms during coitus every time (iii) Seeking medical help in case of doubt and getting it completely cured.

11. State **True** or **False** with explanation.
- Abortion could happen spontaneously too (True or False)
 - Infertility is defined as the inability to produce a viable offspring and is always due to abnormalities in the female partner (True or False)
 - Complete lactation could help as a natural method of contraception. (True or False)
 - Creating awareness about sex related aspects in an effective method to improve reproductive health of the people. (True or False)
- ✓ (a) **True** : Due to internal factors like incompatibility, abortion could happen spontaneously.
 (b) **False** : Infertility can be due to male partner also, when sperm count is less or their motility is less.
 (c) **True** : Lactational amenorrhoea is a method of contraception as ovulation does not occur during this period. It is effective for a maximum period of six months.
 (d) **True** : Creating awareness about sex-related aspects removes the myths and misconceptions about these problems.
12. Correct the following statement.
- Surgical methods of contraception prevent gamete formation.
 - All sexually transmitted diseases are completely curable.
 - Oral pills are very popular contraceptives among the rural women.
 - In E.T techniques, embryos are always transferred into the uterus.
- ✓ (a) Surgical methods of contraception prevent approximation of male and female gametes during intercourse
 (b) Few sexually transmitted diseases are completely curable if detected early and treated properly
 (c) Oral pills are very popular contraceptives among the educated urban women.
 (d) In E.T. techniques, 8-celled embryos are transferred into fallopian tube and more than 8 celled embryos are transferred into the uterus

TEXT QUESTIONS

One Mark Questions (With answers)

- Define Demography.
✓ Scientific study of human population is called Demography.
- On what two factors the population of a species depends ?
✓ Biotic potential and carrying capacity of environment.
- Give India's population according to 1991 and 2001 census?
✓ 844 million, 1 billion.
- What single factor caused population explosion in India ?
✓ Decrease in death rate.
- Why has amniocentesis been banned ?
✓ It is being used for sex-determination to kill the female foetus.
- Elaborate the following abbreviations : (i) RCH Programme (ii) GIFT.
✓ (i) Reproductive and Child Health Care Programme, (ii) Gamete Intra Fallopian Transfer.
- Name the organization that produced 'Saheli' pill.
✓ Central Drug Research Institute (CDRI), Lucknow.
- Who is responsible for the sex of the child, father or mother ?
✓ Father
- List causative agents of the following STDs (i) AIDS (ii) Gonorrhoea.
✓ (i) HIV (Human Immuno deficiency virus), and (ii) *Neisseria gonorrhoeae*.
- How do the oral pills help in birth control ? Name common pills used.
✓ Oral pills contain progesterone and oestrogen which check ovulation ; Mala D and Saheli.

11. Name two new techniques for determining the condition of the foetus.
✓ Chorion villus sampling and ultrasound imaging.
12. Name any copper releasing IUD.
✓ Copper T.
13. Expand IUD and IVF.
✓ IUD — Intrauterine Device. IVF — In vitro fertilization
14. Give full form of CMIS.
✓ Cell mediated immune system
15. Give full form of NACO.
✓ National AIDS Control Organisation.
16. Suggest four measures for control of human population.
✓ (i) Education (ii) Raising of the age of marriage (iii) Family planning (iv) Incentives for small family.
17. Our government has intentionally imposed strict conditions for MTP in our country. Justify giving a reason. (CBSE 2017)
✓ It may lead to the death of many women.

Two Mark Questions (With Sample Answers)

1. In what respects are the developed nations better than the developing nations ?
✓ Developed nations have higher per capita income, lower rate of population growth and better life facilities than the developing nations.
2. What is Periodic abstinence ?
✓ It is one such method in which the couples avoid or abstain from coitus from day 10 to 17 of the menstrual cycle when ovulation could be expected. As chances of fertilisation are very high during this period, it is called fertile period.
3. (a) Expand IUD.
(b) Why is hormone releasing IUD considered a good contraceptive to space children ?
(CBSE 2008)
4. A mother of one year old daughter wanted to space her second child. Her doctor suggested Cu-T. Explain its contraceptive actions. (CBSE 2008)
5. Why do some women use "Saheli" pills ? (CBSE 2009)
6. Name any two copper-releasing Intra Uterine Devices (IUDs). List two reasons that make them effective contraceptives. (CBSE 2009)
✓ **Intra Uterine Devices.** Lipps, Loop.
IUDs increase phagocytosis of sperms within the uterus and in ions released, suppress sperm motility and the fertilising capacity of sperms. The hormone releasing IUDs, in addition make the uterus unsuitable for implantation and the cervix hostile to the sperms. IUDs are ideal contraceptives for the females.
7. Suggest any four aspects of reproductive health which need to be given special attention in the present scenario.
8. Is sex education necessary in schools ? Why ?
9. Do you think that reproductive health in our country has improved in the past 50 years ? If yes, mention any four areas of improvement.
10. List four ill effects of over-population.
11. What is reproductively healthy society ? List two measures to develop such a society. (PSEB 2010)
12. Why is CuT considered a good contraceptive device to space children?
13. Name an oral pill used as a contraceptive by human females. Explain how does it prevent pregnancy. (CBSE 2011)
14. Describe the Lactational Amenorrhea method of birth control. (CBSE 2011)

Three Mark Questions (Short Answer Type)

1. What do you mean by STDs ? Describe Gonorrhoea and Syphilis.
2. Give an account of infertility in human beings.
3. Briefly describe gamete intra Fallopian transfer (GIFT) technique.
4. Write a note on chorionic villus sampling (CVS)

5. Briefly explain natural methods of birth control.
6. (a) List any four characteristics of an ideal contraceptive.
(b) Name two intrauterine contraceptive devices that affect the motility of sperms. (CBSE 2016)

Four Mark Questions

1. A large number of married couples the world over are childless. It is shocking to know that in India the female partner is often blamed for the couple being childless.
(a) Why is your opinion the female partner is often blamed for such situations in India ? Mention any two values that you as a biology student can promote to check this social evil.
(b) State any two reasons responsible for the cause of infertility.
(c) Suggest a technique that can help the couple to have a child where the problem is with the male partner. (CBSE 2016)
2. It is commonly observed that parents feel embarrassed to discuss freely with their adolescent children about sexuality and reproduction. The result of this parental inhibition is that the children go astray sometimes.
(a) Explain the reasons that you feel are behind such embarrassment amongst some parents to freely discuss such issues with their growing children.
(b) By taking one example of a local plant and animal, how would you help these parents to overcome such inhibitions about reproduction and sexuality ? (CBSE 2017)

Five Mark Questions (Long Answer Type)

1. What are the problems and strategies of reproductive health in Indian people ?
2. Explain various special techniques used in assisted reproduction technologies (ART).
3. (a) Give any two reasons for infertility among young couple.
(b) Test tube baby programme is a boon to such couples. Explain the steps followed in the procedure. (CBSE 2010)

Value Based Questions With Answers

1. Sunita told to her friend Kavita that she and her husband are unable to produce a child. Kavita suggested to Sunita that you should go for test tube baby. One day Sunita asked her doctor about artificial insemination. She also asked about effect of tobacco smoking on pregnant lady.
Read the above passage and answer the followings questions.
(i) What is test tube baby ?
(ii) What is artificial insemination?
(iii) What is the effect of tobacco on next generation.
✓ (i) The fusion of ovum and sperm is done outside the body of woman to form a zygote which is allowed to divide to form embryo. This embryo is then implanted in uterus where it develops into foetus which in turn develops into a child. This is called test tube baby.
(ii) In artificial insemination, semen (mostly from husband) is collected and introduced into the woman's (mostly wife) vagina artificially.
(iii) Long use of tobacco product may damage the genetic material and as a result malformed infants may be produced in women who use tobacco products regularly.
2. Mohan noticed that there was no space in the markets or other public places. He shared his observation with his father. His father told him that it is due to increased population.
Read the above passage and answer the following questions.
(i) What are the reasons of population explosion ?
(ii) What are the adverse effects of population explosion ?
(iii) What are your suggestions to control the trend.
✓ (i) A sudden increase in population is due to decrease in death rate and increase in life span because of advances in medical science.
(ii) As resources are limited, it is not be possible to provide food, shelter, education, medical facilities and other public facilities to all our people.
(iii) We should popularise the advantage of small family and methods of birth control.
3. Sandeep saw that in the city at different places the banners were displayed to spread awareness about AIDS.

Read the above passage and answer the following questions :

- (i) What is AIDS ?
 - (ii) What are the methods to stop the spread of AIDS ?
 - (iii) What are the misconceptions about AIDS ?
 - ✓ (i) Acquired Immune Deficiency Syndrome (AIDS) is a fatal disease caused by HIV. It spreads through HIV infected blood transfusion, unprotected sex, sharing syringe with infected person, etc.
 - (ii) Avoid sharing syringes and unprotected sex with persons.
 - (iii) It can not spread by shaking hands, or sharing clothes and living with AIDS patients.
 4. Gurdeep observed that children of some labourers were not having proper clothes and malnourished. These children were from large sized families. Gurdeep suggested the parents of these children that they can control the size of their families by using birth control methods and advised them to go to the nearest primary health centre where such devices are freely available.
- Read the above passage and answer the following questions :
- (i) What are the methods available for birth control ?
 - (ii) What is the additional advantage of using condom?
 5. Your school has been selected by the department of education to organise and host an interschool seminar on 'Reproductive Health-Problems and Practices'. However, many parents are reluctant to permit their wards to attend it. Their argument is that the topic is 'too embarrassing'. Put forth four arguments with appropriate reasons and explanation to justify the topic to be very essential and timely. (CBSE 2015)

Multiple Choice Questions (with Answers)

- (1) Which of the following is the component of oral pills ? (a) Progesterone (b) Oxytocin (c) Relaxin (d) None of these. (AFMC 2009)
- (2) If in a population, natality is balanced by mortality then there will be (a) decrease in population growth (b) zero population growth (c) increase in population growth (d) over population (AFMC 2009)
- (3) Amniocentesis is a process to (a) determine any disease of heart (b) determine any hereditary disease of the embryo (c) know about the disease of brain (d) grow cell on culture medium. (UP CPMT 2009)
- (4) *In vitro* fertilisation is a technique that involves transfer of which one of the following into the Fallopian tube ? (a) Embryo only, upto 8 cell stage (b) Either zygote or early embryo upto 8 cell stage (c) Embryo of 32 cell stage (d) Zygote only. (CBSE PMT Prelims 2010)
- (5) The permissible use of the technique amniocentesis is for (a) detecting sex of the unborn foetus (b) artificial insemination (c) transfer of embryo into the uterus of a surrogate mother (d) detecting any genetic abnormality. (CBSE PMT Prelims 2010)
- (6) Cu ions released from copper-releasing intra uterine devices (IUDs) (a) make uterus unsuitable for implantation (b) increase phagocytosis of sperms (c) suppress sperm motility (d) prevent ovulation. (CBSE PMT Prelims 2010)
- (7) A logistic growth curve depicting a population that is limited by a definite carrying capacity is shaped like the letter (a) J (b) L (c) M (d) S. (DUMET 2010)
- (8) The technique called Gamete Intra Fallopian Transfer (GIFT) is recommended for those females (a) who cannot produce an ovum (b) who cannot retain the foetus inside uterus (c) whose cervical canal is too narrow to allow passage for the sperms (d) who cannot provide suitable environment for fertilization. (AIPMT (Mains) 2011)
- (9) Medical Termination of Pregnancy (MTP) is considered safe up to how many weeks of pregnancy ? (a) Eight weeks (b) Twelve weeks (c) Eighteen weeks (d) Six weeks. (AIPMT (Prelims) 2011)
- (10) The logistic population growth is expressed by the equation (a) $\frac{dN}{dt} = Nr \left(\frac{K-N}{K} \right)$ (b) $\frac{dN}{dt} = rN \left(\frac{K-N}{K} \right)$ (c) $\frac{dN}{dt} = rN$ (d) $\frac{dN}{dt} = rN \left(\frac{N-K}{N} \right)$. (AIPMT (Mains) 2011)
- (11) Saheli is (a) an oral contraceptive for females (b) a surgical sterilization method for females (c) a diaphragm for females (d) a diaphragm used by males (e) a surgical method of sterilization in males. (Kerala PMT 2011)

- (12) Consider the following statements (a – d) each with one or two blanks (i) Bears go into _____ 1 _____ during winter to _____ 2 _____ cold weather (ii) A conical age pyramid with a broad base represents _____ 3 _____ human population (iii) A wasp pollinating a fig flower is an example of _____ 4 _____ (iv) An area with high levels of species richness is known as _____ 5 _____. Which one of the following options, gives the correct fill ups for the respective blank numbers from 1 to 5 in the statements. (a) 3-stable, 4-commensalism, 5-(marsh) (b) 1-aestivation, 2-escape, 3-stable, 4-mutualism (c) 3-expanding, 4-commensalism, 5-biodiversity park (d) 1-hibernation, 2-escape, 3-expanding, 5-hot spot
(AIPMT (Mains) 2011)
- (13) What is the figure given showing in particular ?
(a) Ovarian cancer (b) Uterine cancer (c) Tubectomy (d) Vasectomy
(CBSE PMT Prelims 2012)
- (14) The test-tube Baby Programme employs which one of the following techniques (a) intra cytoplasmic sperm injection (ICSI) (b) gamete intra fallopian transfer (GIET) (c) intra uterine insemination (IUI) (d) zygote intra fallopian transfer (ZIFT)
(CBSE PMT Prelims 2012)
- (15) A vasectomy (a) prevents the production of sperm in the testes (b) prevents the production of semen (c) prevents the movement of sperm into the urethra (d) prevents a man from having an erection.
(J & K CET 2012)
- (16) The population limited to a particular geographic area is called as (a) pandemic (b) endemic (c) alien (d) natural.
(J & K CET 2012)
- (17) Artificial insemination means (a) artificial introduction of sperms of a healthy donor into the vagina (b) introduction of sperms of a healthy donor directly into the ovary (c) transfer of sperms of a healthy donor to a test tube containing ova (d) transfer of sperms of husband to a test tube containing ova.
(NEET 2013)
- (18) Which of the following cannot be detected in a developing foetus by amniocentesis ? (a) Down's syndrome (b) Jaundice (c) Klinefelter's syndrome (d) Sex of the foetus.
(NEET 2013)
- (19) One of the legal methods of birth control is (a) by having coitus at the time of day break (b) by a premature ejaculation during coitus (c) abortion by taking an appropriate medicine (d) by abstaining from coitus from day 10 to 17 of the menstrual cycle.
(NEET 2013)
- (20) Induced abortion is also called (a) STD (b) MTP (c) IUD (d) PID.
(AMU 2013)
- (21) Oral contraceptive prevents pregnancy by (a) killing the ovum (b) blocking fertilization (c) preventing ovulation (d) preventing implantation.
(AMU 2013)
- (22) Which of the following is a hormone releasing IUD ? (a) Multiload 475 (b) Cu7 (c) LNG-20 (d) Cu T.
(J & K CET 2013)
- (23) In case of a couple where a man is having very low sperm count, which of the following techniques will be suitable for fertilization? (a) Infra uterine transfer (b) Gamete intra cytoplasmic fallopian transfer (c) Artificial insemination (d) Intra cytoplasmic sperm injection.
(Maharashtra CET 2014)
- (24) Which is the hormonal method of birth control (a) pill (b) IUD (c) vasectomy (d) femidom. (AMU 2014)
- (25) IUDS which are used by females (a) are implanted under the skin and they release progestogen and estrogen (b) act as spermicidal jellies (c) release copper ions in the uterus that increase phagocytosis of sperm (d) block the entry of sperms into vagina.
(Karnataka CET 2014)
- (26) Which of the following is a hormone releasing Intra Uterine Device (IUD)?
(a) Multiload 375 (b) LNG-20 (c) Cervical Cap (d) Vault.
(AIPMT 2014)
- (27) A childless couple can be assisted to have a child through a technique called GIFT. The full form of this technique is (a) Gamete Inseminated Fallopian Transfer (b) Gamete Intra Fallopian Transfer (c) Gamete Internal Fertilisation and Transfer (d) Germ Cell Internal Fallopian Transfer. (AIPMT 2015)
- (28) Which of the following approaches does not give the defined action of contraceptive ?
- | | |
|-----------------------------|---------------------------------------------------------------------------------------------|
| (a) Intra uterine devices | Increase phagocytosis of sperms, suppress sperm motility and fertilizing capacity of sperms |
| (b) Hormonal Contraceptives | Prevent/retard entry of sperms, prevent ovulation and fertilization |
| (c) Vasectomy | Prevents spermatogenesis |
| (d) Barrier Methods | Prevent fertilization |
- (NEET-I-2016)
- (29) In case of a couple where the male is having a very low sperm count, which technique will be suitable for fertilisation ?



- (a) Gamete intracytoplasmic fallopian transfer (b) Artificial insemination (c) Intracytoplasmic sperm injection (d) Intrauterine transfer. (NEET 2017)
- (30) Match the following sexually transmitted diseases (column I) with their causative agent (column II) and select the correct option.

Column I		Column II	
A. Gonorrhoea		(ii) HIV	
B. Syphilis		(ii) <i>Neisseria</i>	
C. Genital warts		(iii) <i>Treponema</i>	
D. AIDS		(iv) Human papilloma virus	

	A	B	C	D
(a)	(iii)	(iv)	(i)	(ii)
(b)	(iv)	(ii)	(iii)	(i)
(c)	(iv)	(iii)	(ii)	(i)
(d)	(ii)	(iii)	(iv)	(i)

- (31) The function of copper ions in copper releasing IUDs is (a) they inhibit gametogenesis (b) they make uterus unsuitable for implantation (c) they inhibit ovulation (d) they suppress sperm motility and fertilising capacity of sperms. (NEET 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given. One is assertion (A) and one is reason (R). Mark the correct answer as

- (A) If both **A** and **R** are true and **R** is correct explanation of **A**.
 (B) If both **A** and **R** are true but **R** is not the correct explanation of **A**.
 (C) If **A** is true but **R** is false.
 (D) If both **A** and **R** are false

1. **Assertion** : In India, IUDs like placement of copper-T is one of most widely accepted method of contraception.

Reason : Sterilisation procedure in the male is called vasectomy.

- (A) (B) (C) (D)

2. **Assertion** : Sex education in schools is not necessary.

Reason : Sex education may increase certain myths and conceptions in the students

- (A) (B) (C) (D)

3. **Assertion** : Now a days, there are less childless couples.

Reason : A number of measures are now available by which even infertile couples can have child.

- (A) (B) (C) (D)

4. **Assertion** : Over population causes a number of socio-economic problems.

Reason : A number of bacterial and viral diseases have controlled.

- (A) (B) (C) (D)

ANSWERS

Multiple Choice Questions

- (1) —a (2) —b (3) —b (4) —b (5) —d (6) —c (7) —d (8) —a (9) —b (10) —b
 (11) —a (12) —d (13) —c (14) —d (15) —c (16) —b (17) —a (18) —b (19) —c (20) —b
 (21) —c (22) —c (23) —c (24) —a (25) —c (26) —b (27) —b (28) —c (29) —b (30) —d

Assertion and Reason Type Questions

- (1) —B (2) —D (3) —A (4) —B

IMPORTANT TERMS

1. **Character.** The term character is used for the phenotypic property of the individual such as stem height, flower colour, type of hair, etc.

2. **Trait.** It is an inherited character such as tall or dwarf, purple or white colour of flower, curly or straight hair.

3. **Unit Factor.** This term was used by Mendel. It is a unit of inheritance which controls a trait singly in case of haploid and alongwith another factor of similar type in case of diploid.

4. **Gene.** The unit factor of Mendel was called **gene** by Johannsen in 1909. A gene is the unit of inheritance which is carried from parent by a gamete. Gene occurs in a chromosome and controls the expression of a character in cooperation with other genes and environment. Chemically gene is a segment of DNA called **cistron** that has a particular function. One cistron controls the production of one polypeptide.

5. **Symbols used for Genes.** Each trait is given a symbol. There are two types of conventions for allotting symbols.

(i) **After the Dominant Trait.** The first letter of the dominant trait is used in the capital form for representing the dominant trait. The recessive trait is then shown with the small letter of the same symbol, e.g., T for tallness and t for dwarfness.

(ii) **After the Recessive Trait.** The first letter of the recessive trait is used in the small form as a symbol for the recessive trait. The capital form of this symbol is used for representing the dominant trait, e.g., d for dwarfness and D for tallness.

6. **Alleles** (The abbreviated form of the term "**allelomorphs**" Gr. *allelon* – of one another). The term alleles was given by Bateson in 1905. Alleles are forms of the same gene which are found at the same place or locus on homologous chromosomes and control particular traits of a character, e.g., tallness and dwarfness. Now a days the term allele is used for any form of the gene, similar or dissimilar, e.g., TT, Tt, tt.

7. **Locus (pl. loci).** A fixed position or place on a chromosome that is occupied by a given gene or one of its alleles. The allelic genes occupy the corresponding loci in a pair of homologous chromosomes.

8. **Dominant Factor or Allele.** It is one of a pair of alleles which can express itself whether present in homozygous or heterozygous state, e.g., the factor for tallness in hybrid and homozygous states or Tt and TT.

9. **Recessive Factor or Allele.** The factor of an allelic or allelomorphic pair which is unable to express its effect in the presence of its contrasting factor in a heterozygote is called recessive factor or allele, e.g., the allele of t in hybrid tall Pea plant Tt. The effect of recessive factor becomes known only when it is present in the pure or homozygous state, e.g., tt in dwarf Pea plant.

10. **Wild and Mutant Alleles** (Wild and Mutant Phenotypes). Wild allele is the one which was originally present in the population, is dominant and usually widespread. The recessive allele is less common and is believed to be formed through mutation of wild allele. It is, therefore, also called mutant allele.

Differences between Dominant and Recessive Genes

<i>Dominant Gene/Factor/Trait/Allele</i>	<i>Recessive Gene/Factor/Trait/Allele</i>
<ol style="list-style-type: none"> 1. It is able to express itself even in the presence of its recessive allele. 2. It does not require another similar allele to produce its effect on the phenotype, e.g., Tt is tall. 3. Dominant allele or factor can form complete polypeptide or enzyme for expressing its effects, e.g., violet colour of flower in Pea. 	<ol style="list-style-type: none"> 1. Recessive allele or factor is unable to express its effect in the presence of dominant allele. 2. It produces its phenotypic effect only in the presence of a similar allele, e.g., tt is dwarf. 3. The recessive allele forms an incomplete or defective polypeptide or enzyme so that the expression consists of absence of the effect of dominant allele, e.g., white flower colour in Pea.

William Bateson (1861 – 1926) gave the terms genetics, allele, homozygous, heterozygous, F_1 and F_2 .

11. **Homozygote** (Homozygous Individual). The term was introduced by Bateson and Saunders in 1902. It is an individual which contains identical alleles of a gene or factors of a character on its homologous chromosomes. The homozygote is pure for the character and breeds true, that is, it gives rise to offspring having the same trait on self breeding, e.g., TT or tt. It is of two types, **homozygous dominant** (e.g., TT) and **homozygous recessive** (e.g., tt).

12. **Heterozygote** (Heterozygous Individual; Bateson and Saunders, 1902). It is an individual which contains the two contrasting factors of a character or two different alleles of a gene on its homologous chromosomes. It is not pure and is called hybrid for that character. Heterozygote does not breed true on self fertilization, e.g., Tt.

13. **Hybrid**. The heterozygous organism produced after crossing two genetically different individuals is called hybrid. The process of obtaining hybrids or **hybridisation** is employed to improve the quality of economically important plants and animals as it combines the useful traits of different varieties. The harmful effect of recessive traits disappears as the dominant traits of all the characters of the parents often come together in the hybrid. As a result the hybrid possesses qualities better than either of the parents. It is called **hybrid vigour or heterosis**. Depending upon the number of characters in which parents differ from each other, there may be monohybrids (one character), dihybrids (two characters), trihybrids, polyhybrids, etc.



William Bateson

Differences between Homozygous and Heterozygous Individuals

<i>Homozygous Individual</i>	<i>Heterozygous Individual</i>
<ol style="list-style-type: none"> 1. It is pure for a trait and breeds true, i.e., gives rise to similar homozygous individuals. 2. Both the alleles of a character are similar, e.g., TT, tt. 	<ol style="list-style-type: none"> 1. Heterozygous individual is seldom pure and produces offspring with different genotypes on selfing, e.g., TT, Tt and tt on selfing of Tt individuals. 2. It carries dissimilar alleles, e.g., Tt.

3. Homozygous individuals can carry either dominant or recessive alleles but not both.
4. It produces one type of gametes.
5. It does not show extra vigour.

3. Heterozygous individual has both dominant and recessive alleles.
4. It produces two types of gametes.
5. The individual can show extra vigour called hybrid vigour or heterosis.

14. **F₁ Generation.** F₁ or first filial (*filus*– son, *filia*– daughter; Bateson, 1905) generation is the generation of hybrids produced from a cross between the genetically different individuals called parents. For example, Tt individuals are produced in F₁ generation from a cross between TT and tt parents.

15. **F₂ Generation** (Bateson, 1905). F₂ or second filial generation is the generation of individuals which arises as a result of inbreeding or interbreeding amongst individuals of F₁ generation.

16. **Genotype** (Gk. *genos*– race; *typos*– image; Johannsen, 1911). It is the gene complement or genetic constitution of an individual with regard to one or more characters irrespective of whether the genes are expressed or not. For example, the genotype of hybrid tall Pea plant is Tt, pure tall TT and dwarf tt.

17. **Phenotype** (Gk. *phainein*– to appear, *typos*– image; Johannsen, 1911). It is observable or measurable distinctive structural or functional characteristic of an individual with regard to one or more characters which is a result of gene products brought to expression in a given environment. The characteristic may be visible to eye (e.g., height of a plant, colour of flower) or may require special test for its identification (e.g., serological test for blood group). For recessive genes, the phenotype is similar to genotype. For dominant genes, the phenotypic expression can be due to its homozygous genotype or heterozygous genotype. For example, phenotypic tall Pea plant can be genotypically TT or Tt.

Differences between Genotype and Phenotype	
Genotype	Phenotype
1. It is the gene complement of an individual.	1. It is the external manifestation of gene product brought to expression.
2. Genotype remains the same throughout the life of an individual.	2. Phenotype may change with time, e.g., infant, adolescent, young and old.
3. Genotype cannot be studied directly. It can be known through the study of ancestors, mating and offspring.	3. Phenotype can be known through direct observation.
4. It is not influenced by phenotype.	4. Genotype establishes the boundaries within which a phenotype can be expressed.
5. In a given environment or time, individuals with similar genotypes will produce similar phenotypes.	5. Individuals with similar phenotypes may not belong to same genotype.
6. Individuals with different genotypes may have similar phenotype, e.g., tallness for TT and Tt.	6. Individuals with different phenotypes usually have different genotypes.
7. It is not influenced by environment.	7. Phenotypic expression can change with change in environment.

18. **Genome.** It is the entire genetic set of a prokaryote or virus or the haploid genetic set of a eukaryote.

19. **Gene Pool.** The aggregate of all the genes and their alleles present in an interbreeding population is known as gene pool.

20. **Reciprocal Cross.** A second cross of the same genotypes in which the sexes of the parental generation are reversed, is called reciprocal cross. The cross $AA (\text{♀}) \times aa (\text{♂})$ is the reciprocal of the cross $aa (\text{♀}) \times AA (\text{♂})$.

21. **Punnett Square.** It is a checker-board or square divided into smaller squares as shown in the figure 5.1. It was developed by a British geneticist Punnett (1927) and is known after his name as Punnett square. It is a graphical representation to calculate the probability of all possible genotypes of offspring in a genetic cross. The possible gametes are written on two sides, the top row (horizontal row) and left column (vertical column). Usually male gametes are written in top row and female gametes in left column. All possible combinations are represented in boxes below in the squares. Thus various types of phenotypes and genotypes are obtained.

22. **Pollen.** The young male gametophyte of a plant, surrounded by the microspore wall.

23. **Stamens.** These are male reproductive organs of a flower. Stamen consists of two parts— filament and anther.

24. **Pistils.** These are female reproductive organs of a flower. Pistil consists of three parts— stigma, style and ovary. Stigma receives pollen grains during pollination.

25. **Emasculation.** The removal of stamens from bisexual flowers in order to avoid self-pollination in these flowers during hybridization.

26. **Syndrome.** A group of symptoms that occur together and represent a particular disease.

27. **Back Cross.** The cross of an F_1 hybrid with one of the two parents is called **backcross**. In such cases there are two possibilities.

(A) In one possibility, there is cross between F_1 hybrid (Tt) and dominant parent (TT). In such a cross, plants will be 100% tall (Fig. 5.2 A).

(B) In second possibility, there is cross between F_1 hybrid (Tt) and recessive parent (tt). In such cross, plants will be 50% tall and 50% dwarf (Fig. 5.2 B).

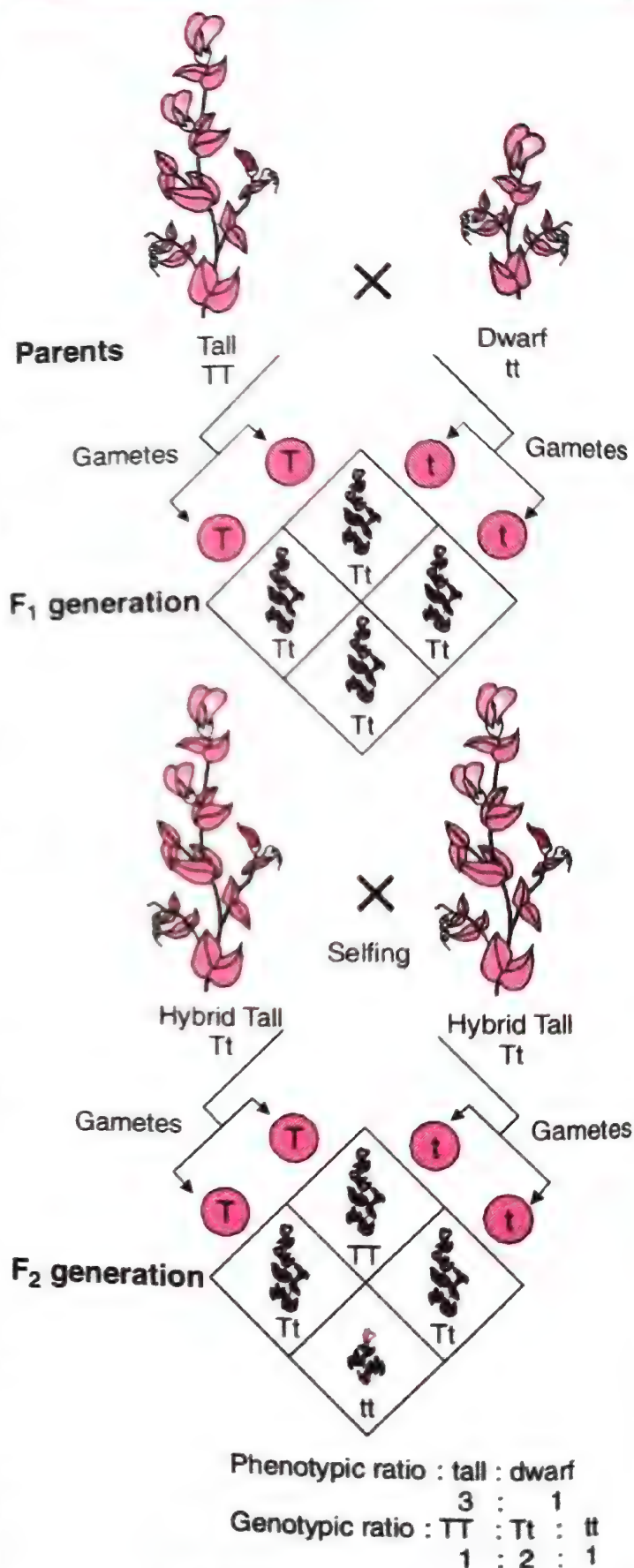
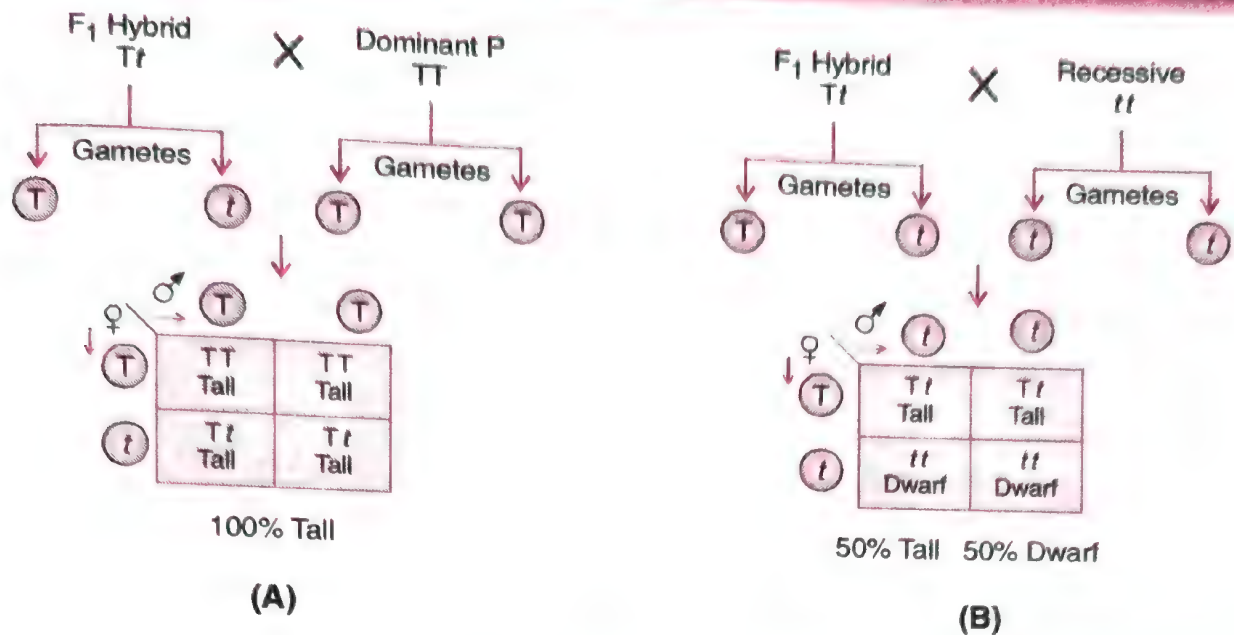


Fig. 5.1. A Punnett square used to understand a typical monohybrid cross.


 Fig. 5.2. Backcrosses of F₁ monohybrids with parental types.

Use of Back Cross. In plant breeding back cross is performed a few times in order to increase the traits of that parent. For example, a crop plant is crossed with a wild variety in order to obtain its disease resistance. In the process most good traits of the crop plant get diluted. The hybrid is, therefore, repeatedly crossed with parent crop plant in order to transfer the good traits back into it.

28. Test cross. A cross between an individual of unknown genotype and recessive parent is called **test cross**.

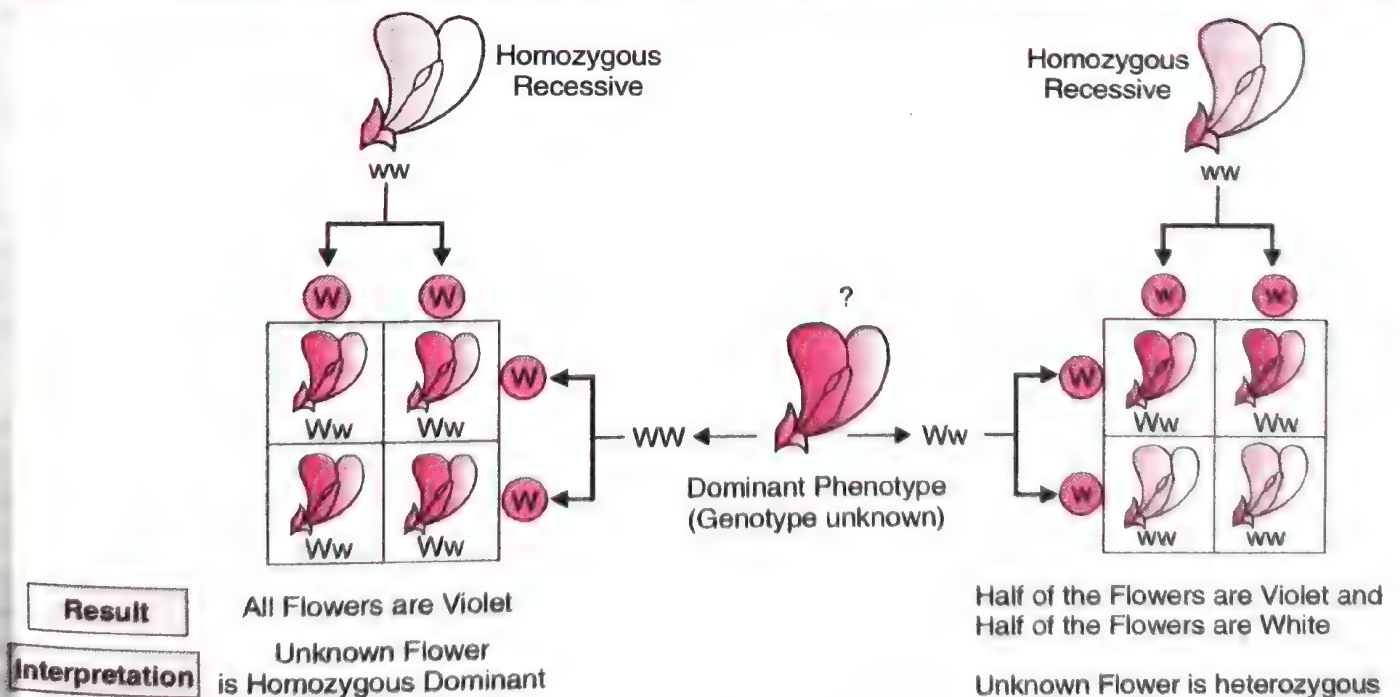


Fig. 5.3. Diagrammatic representation of a test cross.

There are two possibilities of such a cross.

(A) When pure dominant violet parent plant (WW) of unknown genotype plant is crossed with a pure recessive white parent plant (ww), in such a cross, 100% plants will be violet as in the normal monohybrid cross.

(B) When hybrid dominant violet (Ww) plant of unknown genotype is crossed with a pure recessive white (ww) parent plant, in such cross 50% plants will be violet (Ww) and 50% plants will be white (ww).

Use of Test Cross. It is called testcross because it is used to test whether an individual is homozygous (pure) or heterozygous (hybrid). It is also used as test for linkage.

Types of Testcross. Testcross is of two types — Monohybrid and Dihybrid. A **monohybrid test cross** deals with single trait and gives F_1 phenotypic ratio of 1 : 1, i.e., 50% each. A **dihybrid testcross** deals with two traits at a time and gives F_1 phenotypic ratio of 1 : 1 : 1 : 1, i.e., 25% each.

29. **Monohybrid Cross.** It is a cross between two organisms of a species which is made to study the inheritance of a single pair of alleles or factors of a character.

30. **Monohybrid Ratio.** It is a ratio which is obtained in F_2 generation when a monohybrid cross is made and the offspring of F_1 generation are selfbred. Monohybrid ratio is usually 3 : 1 (phenotypic ratio) or 1 : 2 : 1 (genotypic ratio) in which 25% of the individuals carry the recessive trait, 25% pure dominant and 50% have hybrid dominant trait.

31. **Dihybrid Cross.** It is a cross between two organisms of a species which is made to study the inheritance of two pairs of factors or alleles of two genes.

32. **Dihybrid Ratio.** It is a ratio which is obtained in the F_2 generation when a dihybrid cross is made and the offspring of F_1 generation are self-bred. Dihybrid ratio is 9 : 3 : 3 : 1 (phenotypic ratio) where 9/16 individuals carry both the dominant traits, 3/16 first dominant and second recessive, 3/16 first recessive and second dominant and 1/16 carry both the recessive traits.

33. **Trihybrid Cross.** It is a cross between the two individuals of a species for studying inheritance of three pairs of factors or alleles belonging to three different genes.

34. **Trihybrid Ratio.** It is the ratio obtained in F_2 generation when three independently assorting genes are studied. There are eight phenotypes in the ratio of 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1.

35. **Gene Interaction.** It is the influence of an allele over another allele of the same or different gene. It is of two types:— (i) **Intragenic (Interallelic) Interaction.** Influence of one allele over another allele of the same gene, e.g., incomplete dominance, codominance, multiple alleles, lethal genes. (ii) **Intergenic (Nonallelic) Interaction.** Allele of one gene influences the expression of another gene, e.g., epistasis, complementary genes, supplementary genes, duplicate genes.

36. **Pure Line.** The term was coined by Johannsen in 1900, the same year Mendel's paper was discovered. Pure line is the progeny of an organism that is homozygous because of continued inbreeding. In homozygous form both the alleles express the same effect. Such characters do not show any change on continued selfing. Hence, these organisms are said to **breed true**. Natural pure lines do not produce vigorous offspring because several of the defective genes also occur in varieties of important plants are maintained by plant breeding centres for one or more useful homozygous characters like grain colour, nutrient content, disease resistance, size, number of flowers, number of seeds, tillers, root system, etc. They are used for cross breeding in order to get the desired improvement in crops.

37. **Mendel's Mode of Calculations.** Mendel used algebraic methods for calculating the expected combinations. For example, inbreeding of hybrid (say Aa) involves separation of its factors in the gametes and then their random fusion : $(A + a) \times (A + a)$ or $(A + a)^2$ or $AA + 2 Aa + aa$. Similarly, in a test cross the hybrid (say Aa) is crossed with recessive parent (aa). The cross will result in $(A+a) \times a$ or $Aa+aa$.

38. **Theory of Probability.** (i) Out of the two alternate events, the probability of occurrence of each one of them is 50%. (ii) Two events are independent if occurrence of one does not affect the probability of occurrence of the other. (iii) The probability of joint occurrence of two independent events is the product of their individual probabilities. (iv) For an event which can happen through two independent pathways, the probability of its occurrence is the sum of separate probabilities.

39. **Offspring** are the product of sexual reproduction and commonly **biparental** in origin. They resemble their parents, family, tribe, race, variety and species sufficiently that one can recognise them to belong to their particular grouping. However, this resemblance is never 100%. Only monozygotic twins are genetically alike. Otherwise children of the same parents, including dizygotic twins, possess genetic variations. This is not true for asexually reproducing organisms. Here the progeny is **monoparental** or derived from a single parent through the process of mitosis. As a result, the progeny forms a uniform population. It possesses exact copies of genetic characteristics of the parent. These individuals which are carbon copies of one another and/or the parent are called **ramets** while the group of such individuals is known as **clone**. Identical twins are also clones of each other. They are, of course, offspring of their parents.

Differences between Clone and Offspring

Clone	Offspring
1. It is monoparental or derived from a single parent.	1. An offspring is biparental or formed from two parents.
2. Clone is product of asexual reproduction.	2. Offspring is a product of sexual reproduction.
3. It does not involve gametes.	3. It involves the formation and fusion of two gametes.
4. Meiosis does not occur. Clone is a product of mitosis.	4. Meiosis occurs prior to the formation of gametes.
5. There is no recombination of genes.	5. There is a chance segregation and chance recombination of genes during the formation of an offspring.
6. Ramet or individual of a clone does not differ in the genetic constitution from its parent. Rather it is the carbon copy of the latter.	6. Offspring differs in the genetic constitution from either of its parents. It is neither intermediate between the two because some of the genes present in it might not have found expression in the parents.
7. Members or ramets of a clone have the same genotype.	7. Offspring of the same parents or siblings differ in their genotypes.

40. **Species.** A group of organisms capable of interbreeding to produce fertile offspring.

41. **Antigen.** A substance usually protein or polysaccharide molecule usually induces specific antibody production.

42. **Antibody.** A protein in a tissue or fluid of the body, produced in response to the presence of some foreign substance, protects the organism against antigen.

HEREDITY, VARIATION AND GENETICS

Heredity (L. *hereditas*— heirship or inheritance) — There is an old proverb that “like begets like”, that is all living organisms tend to produce young ones like themselves. An elephant always gives birth only to a baby elephant and not some other animal. A mango seed forms only a mango plant and not any other plant. Thus the offspring resemble their parents. **Heredity** is the transmission of genetic characters from parents to their offspring. Heredity is also called inheritance. Inheritance is actually the process by which characters or traits pass from one generation to the next.

Variation. Variation is the degree of differences in the progeny (offspring) and between the progeny and the parents. The term **variation** is also used for a single difference in a trait. In that case the various differences in the traits are termed as **variations** (plural of variation).

Early agriculturists (8000–10,000 BC) knew that causes of variation are hidden in the process of sexual reproduction. Because of it, they successfully bred domesticated varieties from wild plants and animals through selective crossing and artificial selection. Chicken is the domesticated form of Wild Fowl. Indian Cow (*e.g.*, Sahiwal of Punjab) is domesticated form of an ancestral Wild Cow. However, our ancestors had no idea about the scientific basis of inheritance and variation.

Genetics. The branch of biology that deals with the study of heredity and variations is known as **genetics**. The term genetics was given by William Bateson in 1906 who derived it from Greek word ‘*genesis*’ meaning to grow into or to become.

Branches of Genetics

There are three main branches of genetics : Transmission genetics, Molecular genetics and Population genetics.

1. **Transmission Genetics** (Also called classical or Mendelian genetics). It deals with the transmission of genes from one generation to the next. It is dealt in this Chapter.

2. **Molecular Genetics.** It deals with the structure and function of genes at a molecular level. It is dealt in the next Chapter.

3. **Population Genetics.** It deals with the application of Mendel’s laws and other principles of genetics to entire populations of organisms.

Pre-Mendelian Ideas about Inheritance

A number of view points were put forward prior to Mendel to explain the transmission of characters from parents to offspring. They are often called **theories of blending inheritance** as they believed that characters of the parents blended or got mixed during their transmission to the offspring.

1. **Moist Vapour Theory.** Pythagoras (580–500 B.C.) proposed that, during coitus (intercourse), moist vapours from all parts of a male’s body gave rise to a similar body in female’s womb.

2. **Fluid Theory.** Aristotle (384–322 B.C.) suggested that male’s semen was highly purified blood and the female’s menstrual fluid was the female semen which is not as pure as male semen. The two fluids combined during coitus. Female semen provided ‘inert’ fluid for the formation of the embryo and male semen gave form and vitality to the embryo.

3. **Preformation Theory.** The theory of preformation believes that the organism is already present, *i.e.*, preformed in the sperm or egg in a miniature form called **homunculus**.

(Fig. 5.4). Fertilization is required to stimulate its growth. Sperms were observed for the first time by Leeuwenhoek, in 1672. Preformation theory was given by Swammerdam (1679) and advocated by Malpighi (1673). It was believed by a number of workers of that period like Hartsoeker (1694) and Dalempatius (1694). It was supported by Roux as late as 1888 but discarded by Wolff who suggested that organs are formed step by step (theory of epigenesis).

4. Particulate Theory. Maupertius (1698 – 1757) considered that heredity is controlled by minute particles which come from all parts of the body to the reproductive organs. An individual is formed when the particles from male and female combine.

5. Theory of Pangenesis. Darwin (1868) thought that every cell of the body produces a tiny particle called **gemmule** or **pangene**. It contains both the parental characters and variations. All the gemmules or pangenes of the body cells collect in the gametes and are passed on to the zygote where they guide the growth of different parts of the embryo to form an offspring.

6. Theory of Continuity of Germplasm. Weismann (1892) proposed this theory. According to this theory germplasm (protoplasm of germ cells) is 'immortal' and is passed from generation to generation. Somatoplasm (protoplasm of somatic cells) that forms the body is 'mortal' and perishes when the organism dies.

Evidences Against Blending Inheritance

1. Unisexual Trait. The trait of sex does not blend itself in unisexual organisms. Such an organism can either be male or female.

2. Skin Colour. Children of dark and fair coloured parents should be of intermediate colour if blending inheritance is true. This is not the case. The children are often of different colours, some fair-coloured, some dark coloured and others of intermediate colour.

3. Atavistic Traits. Many individuals show ancestral characters not found in immediate parents. The phenomenon is called **atavism** (L. *atavus*— great grandfather, grandfather or forefather), reversion or throw-back. For example, a short tail may be found in some babies. Some persons are able to move pinna or external ear.

4. Particulate Nature. Kolreuter (1760), a German botanist obtained fertile interspecific hybrids in Tobacco. The hybrids did not resemble either of the parents. Hybrids were self pollinated. Some offspring resembled the hybrids while remaining resembled one or the other grand parent in different characters. Thus both smooth and hairiness occurred on the leaves of one generation only to separate in the subsequent generation. This proved that the traits have **particulate** nature and remain **discrete** (separate).

5. Non-Expression of a Trait. John Goss (1822) crossed yellow and green seeded pea varieties. The hybrids were all yellow seeded. The trait of green colour remained hidden because it appeared in next generation (in the form of separate particles).

6. Offspring of Hybrids. Naudin (1862) did not observe parental characters in crosses involving hybrids. The offspring showed traits of grand parents more than their parents, concluded that on repeated crossing of hybrids, their parental types appear in the offspring showing that hybrids contain traits of both the parents though they may not be visible externally.

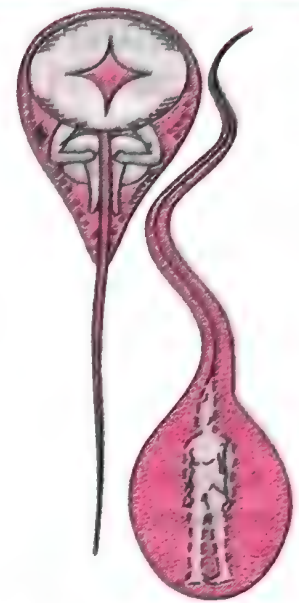


Fig. 5.4. Homunculus in human sperm head. After Hartsoeker (left) and Dalempatius (right).

Basis of Heredity

1. **Physical Basis.** Mendel (1866) proposed that inheritance is controlled by paired **germinal units** or **factors**, now called **genes**. They are present in all cells of the body and are transferred to the next generation through gametes. Factors or genes are thus **physical basis of heredity (carriers)**. They represent small segments of chromosomes. Genes or factors are passed from one generation to the next or from one cell to its daughter cells as components of chromosomes — **chromosomal basis of heredity**.

2. **Chemical Basis.** The genetic material present in chromosomes is DNA. Genes are segments of DNA called **cistrons**. Therefore, DNA is the **chemical basis of heredity**.

Gregor Johann Mendel



Fig. 5.5. Gregor Johann Mendel (1822–1884).

Gregor Johann Mendel (1822 – 1884) is known as **father of genetics**, because he was the first to demonstrate the mechanism of transmission of characters from one generation to the other. He also gave generalisations some of which were later raised to the status of principles or laws of inheritance. They constitute the foundations of genetics. Mendel was born in Silisian, a village in Heinzendorf (Austria; now part of Czech Republic) on July 22, in 1822 to a farmer's family. He was a brilliant student and studied philosophy for several years. After schooling, Mendel joined an Augustinian monastery (religious place) of St. Thomas at **Brunn** (then in Austria; now **Brno** in Czech Republic) in 1843 at the age of 21. At the age of 25 (1847) he was made a priest in the monastery. In 1851, Mendel was sent to University of Vienna for study of Botany and Physics. He returned to Brunn as teacher of Physics and natural Sciences. Mendel served as a teacher for 14 years. Later he was made Abbot (head) of the Monastery. **Gregor** was added to his name when he joined monastery at Brunn. In 1856, Mendel observed the occurrence of two types of seeds in Pea plants growing in his monastery. Thereby he became interested in them. Mendel carried out hybridisation experiments on Garden Pea, *Pisum sativum* for 7 years from 1856–1863. He confirmed the purity of his experimental materials through inbreeding. Initially he took 34 pairs of varieties of Pea plants, then 22 but ultimately worked with only 7 pairs of varieties. The latter differed in such characters as flower colour, flower position, stem height, pod shape, pod colour, seed shape, seed colour, etc. All the selected varieties were **pure lines or true breeding**, that is, they were **pure and bred true** or gave offspring resembling the parents. Mendel performed various types of cross breeding and then allowed the offspring to self breed. His experiments had a large sampling size, some 10000 Pea plants. This gives greater credibility to his data. Further, he was the first to use statistical analysis and mathematical logic in solving problems in biology. He formulated generalisations which were read out at two meetings of Natural History Society of Brunn in 1865. His paper "**Experiments in Plant Hybridisation**" was published in the "**Annual Proceedings of Brunn Natural Science Society**" in 1866. Mendel died in 1884 *without getting any recognition for his work*.

Non-recognition of Mendel's work for about 34 years.

It is because of the following reasons.

1. Limited circulation of the "Proceedings of Brunn Natural Science Society" in which it was published.

2. He could not convince himself about his conclusions being universal since Mendel failed to reproduce the results on Hawkweed (*Hieracium*) undertaken on the suggestion of Naegeli. It was due to nonavailability of pure lines.
3. Lack of aggressiveness in his personality.
4. The scientific world was being rocked at that time by Darwin's theory of evolution (Origin of Species, 1859).
5. Mendel's concept of stable, unblending, discrete units or factors for various traits did not find acceptance from the contemporaries.
6. Mendel's conclusions about heredity were ahead of his time. He used **statistical methods** and mathematical logic which were unfamiliar to other biologists at that time.
7. There was no physical proof for the existence of factors or the material they were made of.

Rediscovery of Mendel's Work

Mendel died in 1884 long before his work came to be recognised. It was in 1900 that three scientists independently **rediscovered** the principles of heredity already worked out by Mendel. They were Hugo de* Vries of Holland, Carl Correns of Germany and Eric von Tschermak-Seysenegg of Austria. Hugo de Vries also found out the paper of Mendel and got it published in 'Flora' in 1901. Bateson, Punnet and other scientists found that Mendel's work was also applicable to animals.



(A)



(B)



(C)

Fig. 5.6. A. Hugo de Vries; B. Carl Correns ; C. Eric von Tschermak-Seysenegg.

Mendel's Experiments

Mendel's Experimental Material. Mendel selected Garden pea (= Edible Pea, *Pisum sativum*; $2n=14$) for his experiments.

Advantages of Selecting Pea Plant

1. **Pure varieties** of Pea were available.
2. Pea plants showed a number of easily detectable **contrasting characters**.
3. The flower structure of Pea is such as to allow controlled breeding. Though plant is self pollinated, but it can be cross bred manually.
4. Pea flower normally remains closed and undergoes self-pollination.

* de means 'of' in French language.

5. It is an annual plant with short life span and gives results within 3 months.
6. A large number of seeds are produced per plant.
7. The plant is grown easily and does not require after-care except at the time of pollination.
8. F_1 hybrids are **fertile**.















Character	Dominant trait	Recessive trait
Seed Shape	 Round (R)	 Wrinkled (r)
Seed/Cotyledon Colour	 Yellow (Y)	 Green (y)
Flower Colour	 Violet (V)	 White (v)
Pod Shape	 Inflated (I)	 Constricted (i)
Pod Colour	 Green (G)	 Yellow (g)
Flower Position	 Axial (A)	 Terminal (a)
Stem Height	 Tall (T)	 Dwarf (t)

Fig. 5.7. Seven pairs of contrasting traits in pea plant studied by Mendel.

Selection of Traits. The term **character** is used for a feature of individual such as flower colour that varies among individuals. An inherited character, such as violet or white colour for flowers is called a **trait**.

Mendel selected 7 pairs of contrasting traits (Fig. 5.7 and Table 5.1). The traits which always appear in two opposing conditions, one dominant and other recessive, are called the **contrasting traits**.

Table 5.1 Characters of Garden Pea picked up by Mendel

Character	Dominant	Recessive
1. Seed Shape	Round (R)	Wrinkled (r)
2. Seed cotyledon Colour	Yellow (Y)	Green (y)
3. Flower Colour/Seed coat colour	Violet (V)	White (v)
4. Pod Shape	Inflated (I)	Constricted (i)
5. Pod Colour	Green (G)	Yellow (g)
6. Flower Position	Axial (A)	Terminal (a)
7. Stem Height	Tall (T)	Dwarf (t)

Mendel's Experimental Technique

Three steps were involved in Mendel's experimental technique. These were selection of pure parent plants, hybridization of pure plants for F_1 generation and self breeding in hybrid plants for F_2 and F_3 generations.

1. Selections of Pure Parent Plants.

Mendel selected 34 varieties for his experiments. He allowed them to self breed for obtaining pure varieties. The number was reduced to 22 and finally Mendel selected 7 pairs of pure or true breeding varieties of pea as the starting material for his experiments. On self pollination or self breeding, a pure variety gives rise to offspring having similar trait, e.g., tall variety with tall offspring, a violet flowered variety with violet flowered offspring, etc. All the characters of selected varieties had easily distinguishable alternate traits, e.g., tallness and dwarfness, violet flowers and white flowers (Table 5.1). Mendel satisfied himself as to true-breeding nature of the variety through self-pollination. Any offspring not true to the form of the trait was eliminated. True breeding plants were then used for the next step. They formed the **parent (P) generation**.

2. Hybridisation of Pure Plants For F_1 Generation. Crossing or mating of two

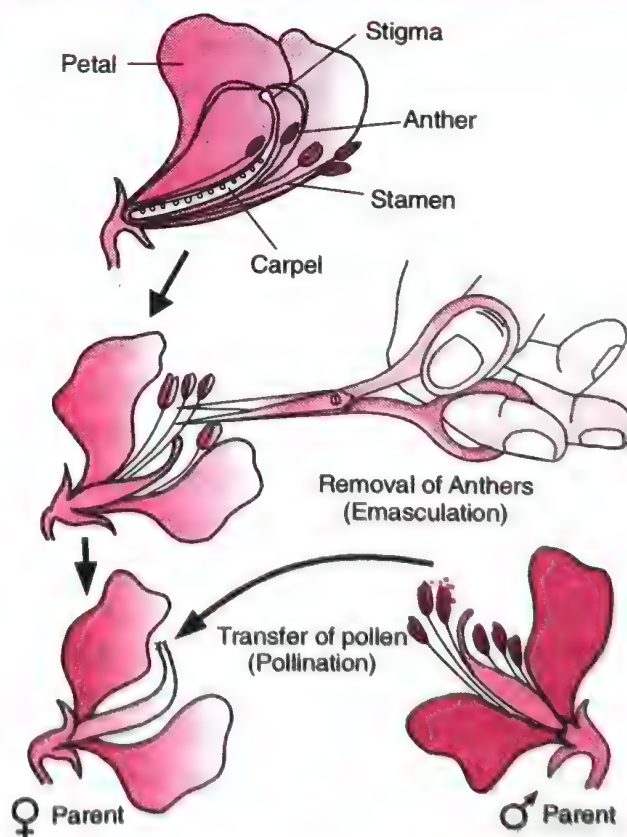


Fig. 5.8. Steps in making a cross in pea.

varieties of plants or animals is known as **hybridisation**. Plants with contrasting traits were cross pollinated. 50% of flowers of same plant were made to function as female parent while remaining 50% were made male parent for that trait. Cross pollination involved dusting off pollen grains of one trait over the stigma of second trait. The various steps were as follows.

(i) ***Emasculation**. Emasculation means removal of male sex organs. In the flowers which were to function as female parent, stamens (male reproductive organs of a flower-stamen consists of two parts filament and anther) were removed before the pollen grains matured. The pistils (female reproductive organs-pistil has three parts, stigma, style and ovary) were also removed from those flowers which were to function as male parent.

(ii) **Bagging**. The flowers were covered with paper bags in order to avoid contamination from foreign pollens.

(iii) **Dusting**. Pollens were collected from flowers selected to function as male parent. They were dusted with the help of fine brush over the stigma of emasculated flowers. Soon after dusting, the flowers were covered.

(iv) **Tagging**. Tags (labels) were attached to the plants indicating the crosses.

(v) **Crosses**. Mendel performed separate crosses involving traits of one character, two characters and three characters which were respectively called **monohybrid crosses**, **dihybrid crosses** and **trihybrid crosses**.

(vi) **Collection of Seeds**. The seeds of the cross or crosses were collected and sown next year. The hybrid offspring including the seeds constitute the first generation. The first generation of Mendel's cross was named the first filial generation, indicated by the symbol F_1 by Bateson and Saunders in 1902. Filial refers to offspring.

3. **Self breeding in Hybrid plants for F_2 and F_3 Generations**. The plants of F_1 generation were allowed to perform self pollination (sibcrossing or selfing). In order to avoid contamination from foreign pollens, the flowers were covered with paper bags from the beginning. Mendel collected the seeds and raised a new generation of plants. The seeds and plants raised from them constitute the **second filial** or **F_2 generation**. Further self pollination produced **F_3 or third filial generation**.

Mendel's Monohybrid Cross (Cross Involving Single Pair of Contrasting Characters)

A cross between two parents that differ in only one heritable character is called **monohybrid cross** and the resulting hybrid is called **monohybrid** (Gr. *monos*— single; L. *hybrida*—mixed offspring). In one such experiment, Mendel selected size of the stem as shown in figure 5.9 and 5.10. The experiment is outlined below.

1. **F_1 Generation**. All stamens from the flowers of the tall stem plants (100–200 cm high) were removed so that the tall stem plants acted as female plants. All the pistils from the flowers of the dwarf stem plants (22–44 cm high) were removed so that the dwarf stem plants acted as male plants. These plants were called **parents** which are now expressed by the symbol **P**. Cross pollination was done in which pollen grains from the dwarf plants were transferred to the stigma of the tall plants.

Mendel collected all seeds formed in the flowers of the tall P and sowed these seeds in his garden. All plants that grew from these seeds had tall stems. He marked these as plants of **F_1 (first filial : *filius* = offspring) generation**.

*Emasculation (L. *e.* — out; *masculus* — male) To deprive of masculine vigour.

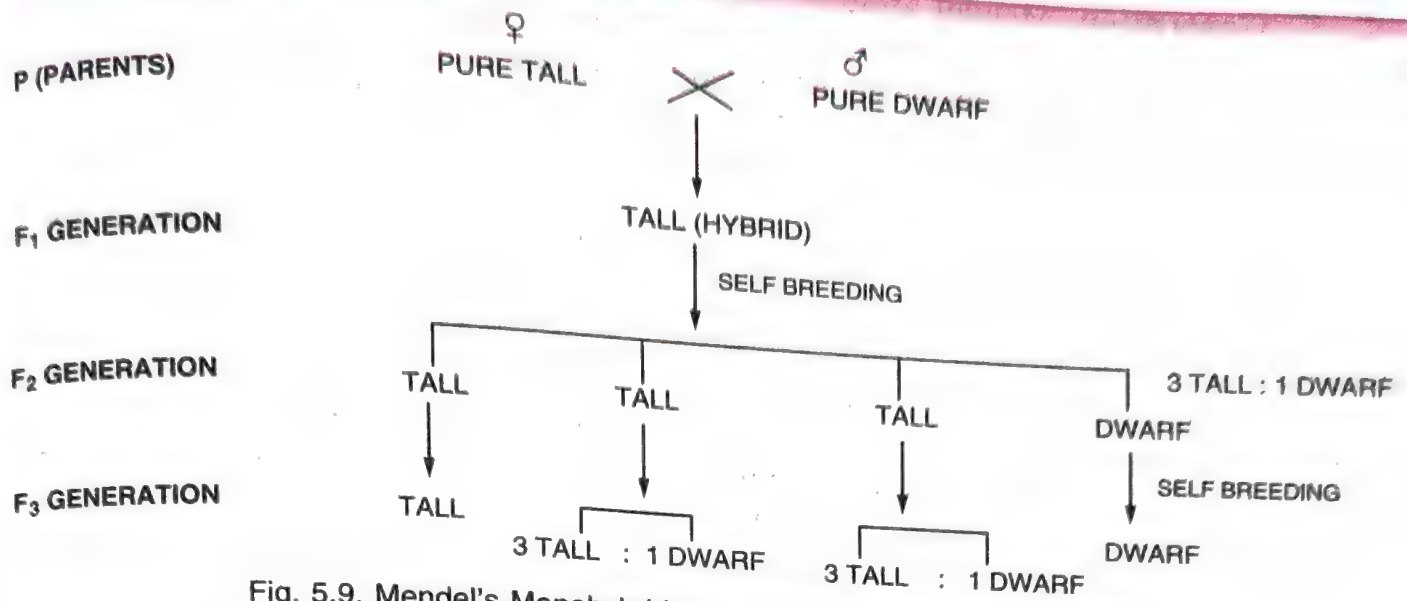


Fig. 5.9. Mendel's Monohybrid cross between a pure tall stem plant and a pure dwarf stem plant up to F₃ generation.

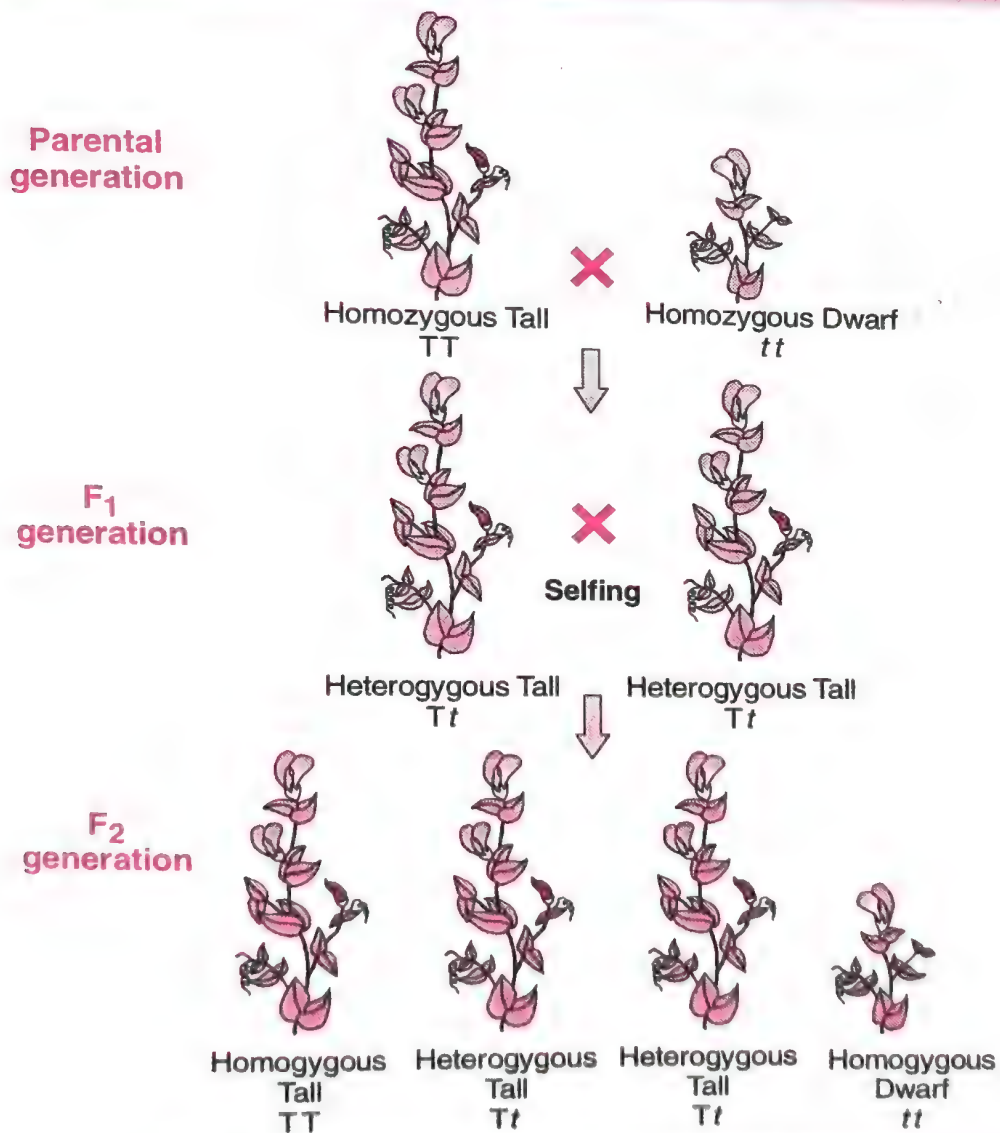


Fig. 5.10. Diagrammatic representation of Monohybrid cross.

2. **F₂ Generation.** Mendel allowed the plants of F₁ generation to reproduce by self-pollination and their seeds were obtained. When he sowed these seeds, these seeds grew into tall stem plants and dwarf-stem plants of **F₂ generation**, giving nearly a 3 : 1 ratio of tall stem and dwarf stem plants (Table 5.2). Most significant feature of this experiment was that dwarfness disappeared in F₁ generation but reappeared in about 25% plants of the F₂ generation.

3. **F₃ Generation.** Mendel allowed the plants of F₂ generation to reproduce by self-pollination. The seeds produced by all the F₂ plants were grown from them. These plants formed F₃ generation.

Mendel observed that all dwarf stem plants of F₂ generation were pure-breeding but of the tall-stem plants of F₂ generation, only about one-third were pure breeding for tallness, while the remaining two thirds produced both tall stem and dwarf-stem plants in 3 : 1 ratio exactly like the hybrid plants of F₁ generation (Fig. 5.10).

Calculations. Mendel maintained record of each crossing from F₁, F₂ to F₃ generations. The ratios were analysed on the basis of law of probability. For example, true breeding tall stem plants were crossed with true breeding dwarf stem plants. All the F₁ plants were tall stem plants. The plants of F₁ were allowed to self breed. Out of F₂ 1064 plants, 787 were tall plants while 277 were dwarf plants. The actual ratio of tall plants to dwarf plants was 787 : 277 = 2.84 : 1, which was approximately equal to 3 : 1. The ratio 3 : 1 is known as the monohybrid ratio. The results of Mendel's Monohybrid crosses involving seven pairs of contrasting characters are given in Table 5.2.

Table 5.2. Results of Mendel's Monohybrid crosses involving seven pairs of contrasting characters in Garden Pea (*Pisum sativum*)

Trait	Parental Cross	F ₁ Generation	F ₂ Generation	Monohybrid Ratio (Actual)	Approximate Ratio
1. Seed* shape	Round × wrinkled	All round	5,474 round <u>1,850 wrinkled</u> 7,324 total	2.96 : 1	3 : 1
2. Seed/cotyledon colour	Yellow × green	All yellow	6,022 yellow <u>2,001 green</u> 8,023 total	3.01 : 1	3 : 1
3. Flower or Seed coat colour	Violet × white	All Violet	705 Violet <u>224 white</u> 929 total	3.15 : 1	3 : 1
4. Pod Shape	Inflated × constricted	All inflated	882 inflated <u>299 constricted</u> 1181 total	2.95 : 1	3 : 1
5. Pod colour	Green × yellow	All green	428 green <u>152 yellow</u> 580 total	2.82 : 1	3 : 1

*Wrinkled seeds are produced due to absence of enzyme SBE (starch branching enzyme) so that starch is not formed and free sugar remains there that results in wrinkling of seeds.

6. Flower position	Axial × terminal	All axial	651 axial 207 terminal 858 total	3.14 : 1	3 : 1
7. Stem height	Tall × dwarf	All tall	787 tall 277 dwarf 1064 total	2.84 : 1	3 : 1

Reciprocal Cross. A second cross of the same genotypes in which the sexes of the parental generation are reversed is called reciprocal cross which gives the same result.

Table 5.3. Original and Reciprocal Crosses give same result.

	Male gamete	Female gamete	Offspring
Original Cross	T	t	Tt
Reciprocal Cross	t	T	Tt

For example, if in the original cross pollen from the flowers of a tall stem pea plant were transferred to stigma of the flowers of a dwarf stem plant; in a reciprocal cross, pollen from flowers of a dwarf stem plant are deposited on the stigma of the flowers of a tall stem plant, similar result was obtained with reciprocal cross also.

Mendel also conducted similar monohybrid crosses to study the inheritance of remaining six genetic traits selected by him. In each case, he obtained almost similar results.

Results (Findings) of Mendel's Monohybrid Cross

1. Mendel proposed that “somethings” were passed unchanged from parent to offspring through the gametes, over successive generations. Mendel called these “somethings” as “factors”. According to him each character is controlled by two factors (**unit factors** or **paired factors**).

2. F_1 plants of reciprocal crosses were similar.

3. F_1 plants were not intermediate between the two alternate traits of a character. Rather, they resembled one parent in having a single alternate trait of the character. Thus in a cross between tall and dwarf stem plants, the hybrids were all tall (Fig. 5.9).

4. In F_2 generation both the parental traits of the character are expressed.

5. One trait of the character which did not appear in F_1 generation must lie hidden or unexpressed in it.

6. Out of the two factors representing the alternate traits of a character, one is **dominant** and expresses itself in the hybrid or F_1 generation. The other factor is **recessive** and does not show its effect (**dominance**).

7. There is no mixing of the two factors in the hybrid.

8. At the time of gamete formation, the two factors separate or segregate and pass into different gametes. A gamete comes to have one factor of a pair. Thus Mendel predicted the occurrence of meiosis long before it was discovered. The gametes fuse randomly during fertilization so that factors come together in new generation and express themselves freely.

9. The two traits of the character appear in F_2 generation in ratio of three dominant to one recessive, 3 : 1. It is also called **monohybrid ratio** (Table 5.2). For example, in the character of stem height (cross tall × dwarf) Mendel obtained 787 tall and 277 dwarf stem

plants (ratio 2.84 : 1). A similar result for flower colour was 705 violet to 224 white (ratio 3.15 : 1).

10. In F_3 generation recessive (e.g., dwarf or white flowered) plants produce similar types. Out of remaining or dominant parents (F_2 plants), one third breed true while two third behave like plants of F_1 generation (Fig. 5.9). This is possible only when the two factors of a character segregated during gamete formation (**segregation**) and come together in the offspring at random according to the law or principle of probability.

Mendel's Dihybrid Cross (Cross Involving Two Pairs of Contrasting Characters)

A breeding experiment dealing with two heritable characters at the same time is called a **dihybrid cross**. In such cross the parent plants differed in two pairs of contrasting traits. In one experiment, Mendel considered form of seeds and colour of seeds. He crossed a pea plant having round and yellow seeds with a pea plant with wrinkled and green seeds. All the plants of F_1 generation had round and yellow seeds suggesting that round was dominant over wrinkled and yellow was dominant over green. Plants of F_1 generation, on selfing (i.e., pollinating among themselves) produced four kinds of plants in F_2 generation (Fig. 5.11).

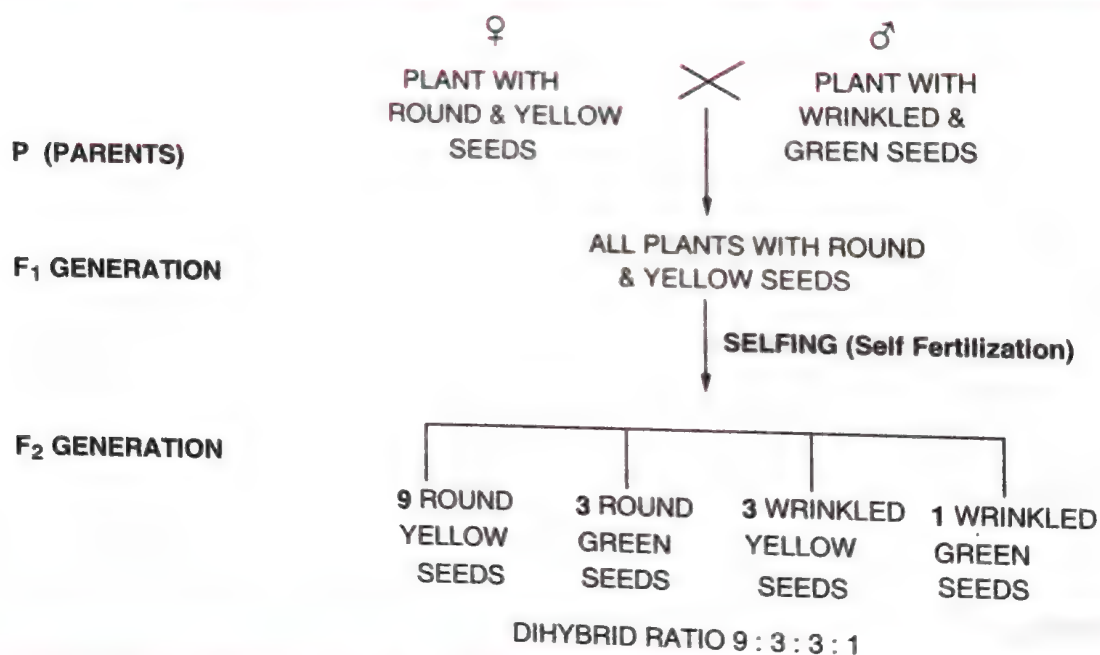


Fig. 5.11. Mendel's dihybrid cross.

Mendel actually collected a total of 556 F_2 seeds and counted them shape wise and colour wise. He got the following result.

Round yellow seeds 315

Round green seeds 108

Wrinkled yellow seeds 101

Wrinkled green seeds 32

Round yellow seeds	Round green seeds	Wrinkled yellow seeds	Wrinkled green seeds
= 315	108	101	32
= 9	3	3	1

Phenotypic ratio : Round yellow : Round green : Wrinkled yellow : Wrinkled green
 seeds seeds seeds seeds
 9 3 3 1

Genotypic ratio : $\overbrace{1 : 2 : 2 : 4}^{\text{Round green and wrinkled yellow seeds were recombinants.}}$: $\overbrace{1 : 2}^{\text{Round green and wrinkled yellow seeds were recombinants.}}$: $\overbrace{1 : 2}^{\text{Round green and wrinkled yellow seeds were recombinants.}}$: $\overbrace{1}^{\text{Round green and wrinkled yellow seeds were recombinants.}}$

Round green and wrinkled yellow seeds were recombinants.

Results (Findings) of Mendel's Dihybrid Cross

(i) **Four Types of Plants.** Four types of plants were produced in the F_2 generation in the ratio of 9 (both dominant) : 3 (one dominant second recessive) : 3 (one recessive second dominant) : 1 (both recessive).

(ii) **New Combinations.** Two new combinations of traits : round green and wrinkled yellow, had appeared in a dihybrid cross.

(iii) **Independent Assortment of Factors.** The formation of four types of individuals in the F_2 generation of a dihybrid cross shows that the factors of the two characters assort (select) independently which leads to the formation of independent assortment (selection) of factors.

Mendel's Trihybrid Cross (Cross Involving Three Pairs of Contrasting Characters)

Mendel conducted trihybrid crosses that involved 3 pairs of contrasting traits at the same time. The results of these crosses can be analysed by applying the principles of segregation and independent assortment.

Reasons for Mendel's Success

1. Mendel selected only pure breeding varieties of Pea (*Pisum sativum*) for his experiments. He took two years (1857–1859) for checking that his experimental materials are pure breeding.
2. Mendel took only those traits for his studies which did not show linkage, interaction or incomplete dominance.
3. Characters chosen by Mendel had distinctive contrasting traits like tall and dwarf or green and yellow.
4. Mendel took one or two characters at one time for his breeding experiments while his predecessors often studied all the traits simultaneously.
5. Mendel studied the inheritance of a character for three or more generations.
6. He performed reciprocal crosses and raised large progenies.
7. Mendel's experimental plant Pea (*Pisum sativum*) is ideal for controlled breeding. It is cross-bred manually while normally it undergoes self breeding.
8. He took care to avoid contamination from foreign pollen grains brought by insects.
9. Mendel kept a complete record of every cross, subsequent self breeding and the number of seeds produced.
10. Mendel experimented on a number of plants for the same trait and obtained hundreds of offspring. A large sampling size gave credibility to his results.
11. He formulated theoretical explanations for interpreting his results. His explanations were further tested by him as to their validity.

12. Mendel used statistical methods and law of probability for analysing his results.

13. Mendel was lucky in selecting those traits, the factors (now called genes) of which did not interact. They were either present on different chromosomes or showed complete recombination. He did not combine pod shape and plant height in any of his dihybrid crosses the genes of which are close together on chromosome 4 and do not show frequent recombination.

14. He did not attempt to explain all the variations found in his results but left them as such, e.g., linkage of flower and seed colour.

THE CHANGING CONCEPT OF INHERITANCE

Mendel proposed that "something" was being passed down from the parents to offspring through the gametes over successive generation. This "something" was called by him a **factor** or **determiner**. According to him there is a pair of factors for each character, one inherited from each parent. **Johannsen** (1909) gave the term '**gene**' to the Mendelian factor. **Alleles** are slightly different forms of the same genes.

Genes are present on the chromosomes. A gene is considered to control the inheritance of one character (**unit of function**). But it was soon realized that a gene does not produce a character itself, although it may exercise the major control on its development. During 1940, it became evident that a gene controlled a single biochemical reaction by directing the production of a single enzyme (**one gene – one enzyme hypothesis**). But soon after, it was shown that one gene produces a single polypeptide and not one enzyme (**one gene one polypeptide hypothesis**). It is further established that gene is chemically a linear segment of DNA, now called **cistron**. Thus one cistron controls the production of one polypeptide in protein synthesis. Cistron is, therefore, considered unit of function and is accepted as a synonym for gene. **Recon** is subunit of cistron that undergoes recombination. **Muton** is also subunit of cistron that is capable of mutation. The terms cistron, recon and muton were given by **S. Benzer** in 1955.

Points To Remember

- Mendel himself did not propose any genetical principle or law. He simply gave conclusive theoretical and statistical explanations for his hybridization experiments in his research paper.

- It was **Correns** (1901) one of the three rediscoverers of Mendel's work who thought that Mendel's discovery could be the two Laws of heredity/inheritance which were named after Mendel's name. These laws of heredity/inheritance are ***Law of Segregation** (it is also called **Mendel's First Law** because this was actually the first law to be rediscovered) and the **Law of Independent Assortment** (it is also called Mendel's **Second Law**). Later on Mendel's postulate of dominance was raised to the status of ***Law of Dominance** by Correns (1901) but this law was not given any serial number.

- Mendel confirmed his own findings in pea with those in rajma (*Phaseolus vulgaris* L).

- The term allele/alleles is usually used instead of factor/factors while describing the Mendel's Laws of Inheritance.

- Mutation may change a gene into two or more alternative forms called alleles.

- Mendel did not know of genes, alleles and even chromosomes.

- DNA is usually genetic material but in some viruses such as (i) Tobacco Mosaic Virus.

(ii) Influenza virus and (iii) Human Immunodeficiency virus, the genetic material is RNA.

*In NCERT Biology Text Book for class XII it is incorrectly mentioned as 'the First Law or Law of Dominance and the second Law or Law of segregation.

MENDEL'S LAWS/PRINCIPLES OF INHERITANCE

The study of the Mendel's laws of inheritance (heredity) is called **Mendelism**. There are three Mendel's laws of inheritance : Law of Dominance, Law of Segregation (both laws are based on monohybrid cross) and Law of Independent Assortment (this law is based on dihybrid cross).

INHERITANCE OF ONE GENE

Every character is controlled by a gene that has at least two alleles (**monogenic inheritance**). *Study of inheritance of single gene (one pair of alleles) of a character at a time (monohybrid cross) is called inheritance of one gene.*

Each organism has a large number of characters, e.g., height, skin colour, flower colour, etc. Each character is represented in an individual by **two unit factors**, now called **alleles**. The alleles occupy the same gene locus on the two homologous chromosomes. When both the alleles represent the same gene, the condition is called **homologous**, e.g., TT, tt. When two alleles represent different traits of same character the individual having such a pair of alleles is called **heterozygous** or **hybrid**, e.g., Tt.

- Sometimes it is incorrectly referred to as "Principle of two unit factors or paired factors".
- **Pleiotropy** (condition in which a single gene influences more than one trait) and **Multiple Alleles** (a condition in which a particular gene occurs in three or more allelic forms in a population of organism) can not be explained by two unit factors or paired factors.

Law of Dominance

Mendel's postulate of dominance was raised to the status of Law of Dominance by Correns (1901).

Statement. (i) Characters are controlled by discrete (distinct) unit called factors, now called alleles. (ii) Alleles occur in pairs. (iii) *Out of two alleles, only one allele expresses itself in the hybrid and prevents the expression of the other allele. The allele which expresses itself in the hybrid is called dominant allele and the other allele which is unable to express in the hybrid is termed recessive allele.*

A capital letter is assigned to dominant allele. A corresponding small letter is assigned to the recessive allele, e.g., T (tallness) and t (dwarfness) respectively. Mendel experimented with *Pisum sativum* for seven characters only. In each case he found that one expression or trait of the character, (e.g., T or tallness in case of height) is dominant over the other expression or trait of the character, (e.g., t or dwarfness in case of height, Table 5.1).

Explanation. This can be proved experimentally.

Take two Pea plants, one pure or homozygous tall (height 100–120 cm) and the other pure or homozygous dwarf (height 22–44 cm). Cross the two and raise their progeny called first filial or F₁ generation. All plants of F₁ generation are tall (height 100 – 120 cm) though they have also received an allele for dwarfness. That the allele for dwarfness is present in F₁ plants can be tested by self breeding them when individuals of F₂ generation will be both tall and dwarf in the ratio of 3 : 1. Therefore, in F₁ plants both the alleles for tallness and dwarfness are present. However, the allele for dwarfness is unable to express itself in the presence of allele for tallness. Hence, the allele for tallness is **dominant** over the factor for dwarfness. The allele for dwarfness is **recessive**.

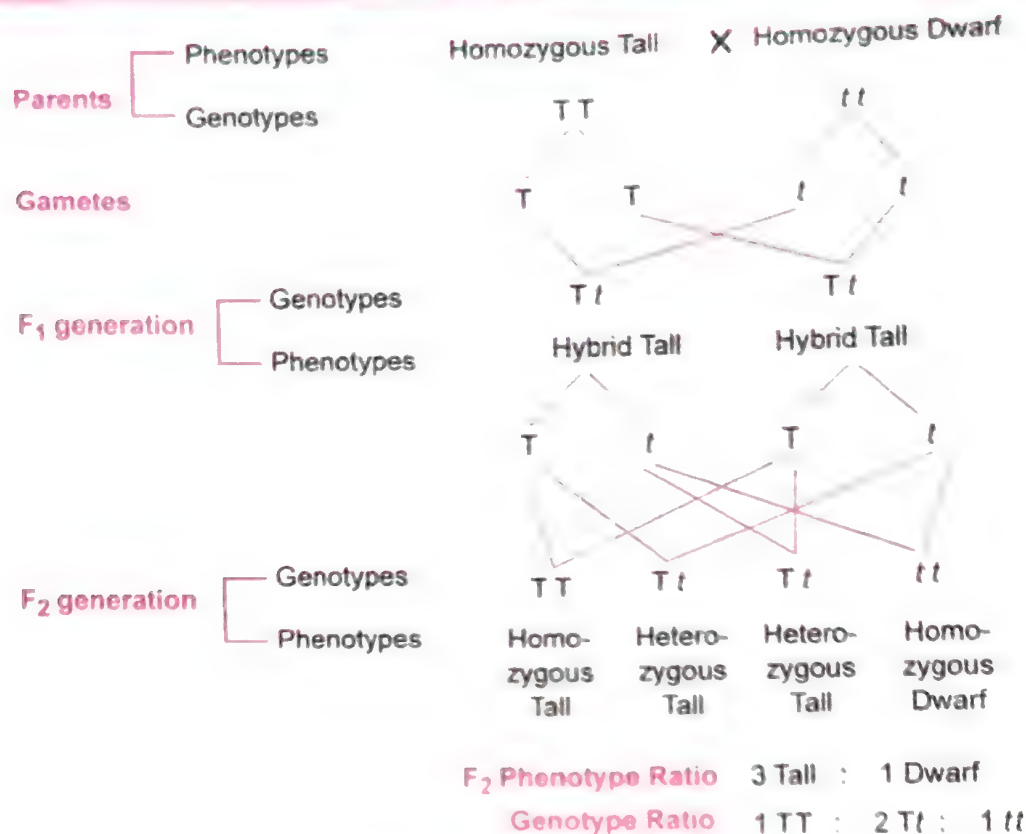


Fig. 5.12. Monohybrid cross showing law of dominance in pea plants.

Significance. (i) It explains why individuals of F_1 generation express trait of only one parent. (ii) Law of dominance is able to explain the occurrence of 3 : 1 ratio in F_2 individuals. (iii) It indicates why mixed population is superior as it hides many of the defective recessive alleles.

Exceptions To Law of Dominance. Incomplete dominance and co-dominance are exceptions to law of dominance.

Law of Segregation

This law has been called **Mendel's First Law** by Correns (1901).

Statement. According to the law of segregation *two alleles of a gene controlling each character stay together in the individual, but during gamete or spore formation by meiosis, the alleles of a pair segregate (separate) from each other so that a gamete or spore carries only one allele of a character.* Since one gamete or spore contains one allele of each character, all gametes or spores are always pure, the law of segregation is, therefore, also called the **law of purity of gametes or spores.**

This law is based on the fact that the alleles do not show any blending (mixing) and both the characters are recovered as such in the F_2 generation though one of these is not seen in F_1 generation.

Of course, a homozygous parent produces similar gametes while a heterozygous parent produces two kinds of gametes each having one allele with equal proportion.

The two important consequences of this law are : (i) each gamete/spore contains only one allele of a gene and (ii) a 3 : 1 ratio is obtained in the F_2 generation of a monohybrid cross. Therefore, the 3 : 1 ratio is commonly known as the **monohybrid ratio.**

Explanation. The law of segregation can be explained with the help of monohybrid cross, say between a pure tall pea plant and dwarf pea plant. The hybrids or plants of first filial (F_1) generation are all tall though they have also received the allele for dwarfness. It is because the allele for tallness is dominant while the factors for dwarfness is recessive. If the hybrids are allowed to self breed, the plants of the second filial or F_2 generation appear to be both tall and dwarf in the phenotypic ratio of 3:1 (Fig. 5.13). Further self breeding of these plants shows that the dwarf plants breed true (tt), i.e., produce only dwarf plants. Amongst tall plants, $1/3$ breed true, that is, yield only tall plants. The remaining $2/3$ of the F_2 tall plants or 50% of the total F_2 plants behave as hybrid plants and produce both tall and dwarf plants in the ratio 3 : 1.

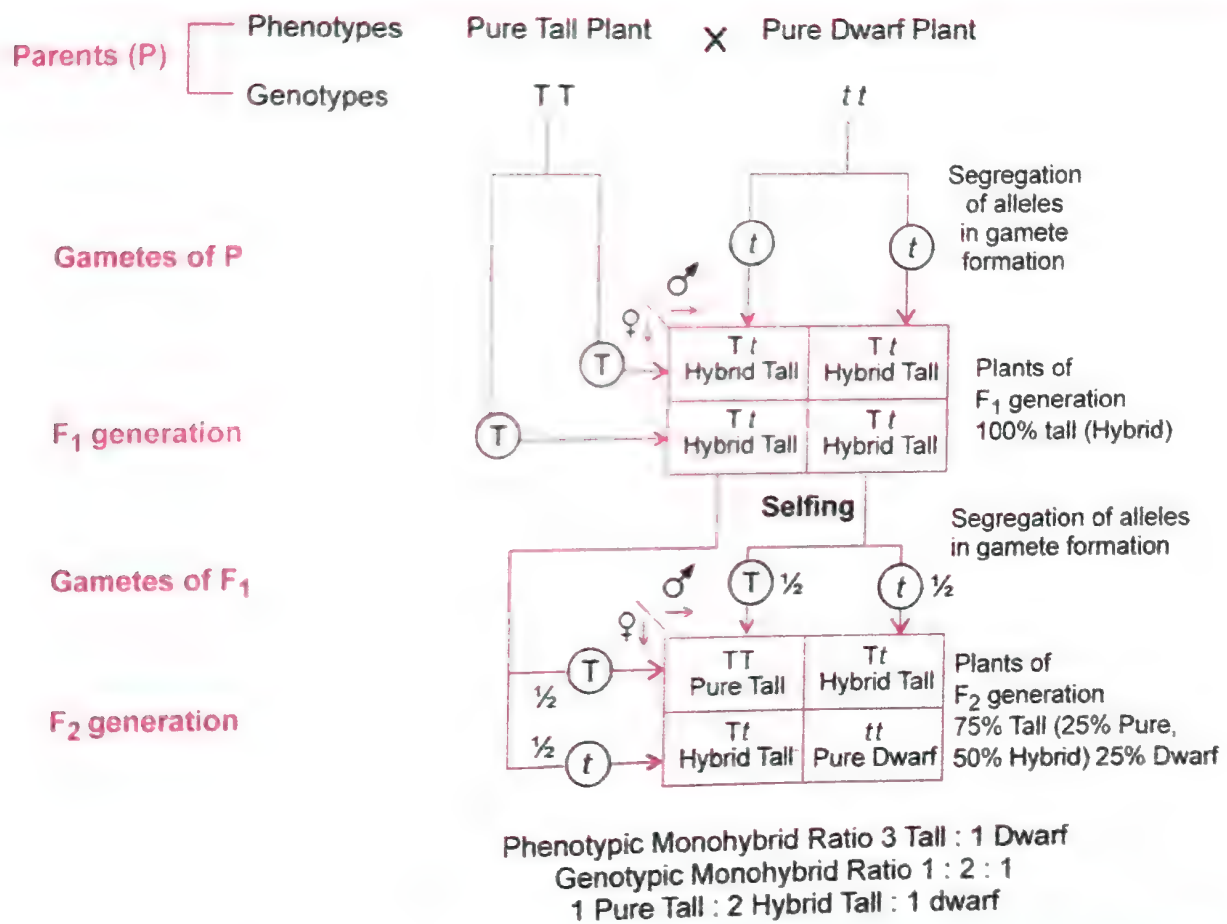


Fig. 5.13. A monohybrid cross in pea plants showing law of segregation.

Therefore, the F_2 phenotypic ratio of 3 : 1 is genotypically 1 pure tall : 2 hybrid tall : 1 dwarf. The above cross shows that

(i) Though F_1 plants show only one alternative or dominant trait of a character, it actually carries alleles of both the traits of the character because the second alternative or recessive trait appears in the F_2 generation. Therefore, F_1 plants are genetically hybrid, in the above case Tt .

(ii) F_1 plants are a product of fusion of male and female gametes. As they carry the gene complement of Tt , the fusing gametes must bring in only one allele each (T from TT and t from tt parent).

	Male Gamete	Female Gamete	Offspring
Original Cross	T	t	Tt
Reciprocal Cross	t	T	Tt

(iii) F_2 generation is produced by self breeding of the F_1 plants. F_2 generation consists of three types of plants— pure tall, hybrid tall and dwarf. This is possible only when (a) The two alleles present in the F_1 plants *segregate* during gamete formation. (b) Gametes carry a *single allele* for a character, 50% of one type and 50% of the second type. (c) The alleles get distributed randomly in the offspring due to random or chance fusion of gametes during fertilization.

Homologous chromosomes carry alleles. There are two homologous chromosomes of each type. Which carry two alleles of each character. Sexual reproduction requires meiosis for formation of gametes. Meiosis reduces the number of chromosomes to half. A gamete carries only one chromosome of each type, therefore, only one of the two alleles passes into a gamete, 50% of the male and female gametes formed by F_1 plant possess the allele for tallness while the remaining 50% carry the allele for dwarfness. Their random fusion results in the following :

Male Gamete		Female Gamete	Offspring
$\frac{1}{2}$ T	×	$\frac{1}{2}$ T	$\frac{1}{4}$ TT (pure tall)
$\frac{1}{2}$ T	×	$\frac{1}{2}$ t	$\frac{1}{4}$ Tt (hybrid tall)
$\frac{1}{2}$ t	×	$\frac{1}{2}$ T	$\frac{1}{4}$ Tt (hybrid tall)
$\frac{1}{2}$ t	×	$\frac{1}{2}$ t	$\frac{1}{4}$ tt (dwarf or pure dwarf)

1 Pure Tall : 2 Hybrid Tall : 1 Dwarf

Appreciation of Law of Segregation. The law of segregation is the most fundamental principle of heredity that has universal application with **no exception**. Some workers like Bateson call the law of segregation as the law of purity of gametes/spores because segregation of the two alleles of a trait results in gametes or spores receiving only one allele out of a pair. As a result gametes/spores are always pure for a character. It is also known as **law of non-mixing of alleles**.

Important Prediction. In the event of segregation, it was predicted the occurrence of meiosis long before it was discovered.

- Segregation may not occur under abnormal condition such as **nondisjunction**.

Differences between Monohybrid Cross and Reciprocal Cross

Monohybrid Cross	Reciprocal Cross
1. It is one-sided or both sided.	1. It is a both sided cross in which female of one type is crossed with male of the second type and <i>vice versa</i> .
2. It studies the inheritance of a single trait.	2. It may study inheritance of one, two or more traits.
3. A single sided monohybrid cross cannot distinguish between nuclear and cytoplasmic or sex-linked and autosomal traits.	3. A reciprocal cross can distinguish between nuclear and cytoplasmic inheritance as well as sex-linked and autosomal inheritance.

INHERITANCE OF TWO GENES

To verify his results of monohybrid crosses, Mendel also crossed pea plants differing in two characters (dihybrid cross). This helped him to understand inheritance of two genes (*i.e.*, two pairs of alleles) at a time. *Study of inheritance of two genes (i.e., two pairs of alleles) of two characters at a time (dihybrid cross) is called inheritance of two genes.* It was found that inheritance of one pair of alleles (one character) does not interfere in the inheritance of other pair of alleles (second character). Based upon it, Mendel proposed another set of generalisations (postulates) which is now called law of independent assortment.

Law of Independent Assortment

It has been called **Mendel's Second Law** by Correns.

Statement. *According to this law the alleles of two pairs of traits separate independently of each other during gamete or spore formation and get randomly rearranged in the offspring at the time of fertilization, producing both parental and new combinations of traits.*

In fact, there is occurrence of two important events. **First** is separation of the alleles of two pairs of traits independently of each other during gamete or spore formation. **Second** is rearrangement of alleles (random union of alleles) in the offspring at the time of fertilization.

Explanation. This law can be explained with the help of dihybrid cross.

A cross is made between a pure round yellow seeded pea plant (RRYY) with wrinkled green seeded pea plant (rryy). Yellow colour is dominant over green and rounded seed shape over wrinkled seed shape. F_1 plants (hybrid plants) are all round and yellow seeded. F_1 plants are allowed to self breed and produce F_2 generation. F_2 generation has four types of plants—rounded yellow, rounded green, wrinkled yellow and wrinkled green in the ratio of 9 : 3 : 3 : 1. Each of the character if considered separately shows a ratio of 3 : 1 as found in monohybrid cross.

Seed Colour	Yellow $9 + 3 = 12$
	Green $3 + 1 = 4$

Ratio between yellow and green = $12 : 4$ or $3 : 1$

Seed Shape	Round $9 + 3 = 12$
	Wrinkled $3 + 1 = 4$

Ratio between round and wrinkled = $12 : 4$ or $3 : 1$

The F_2 ratio of 9 : 3 : 3 : 1 further shows two types of recombinants, wrinkled yellow and rounded green. They can be produced only if the alleles of the two different characters are free to recombine, *i.e.*, separate and combine independent of each other. The same can be confirmed with the help of **Punnet square**.

Exception To Law of Independent Assortment. The law of independent assortment is applicable to only those factors or genes which are either located distantly on the same chromosome or occur on different chromosomes. Actually a chromosome bears hundreds of genes. All the genes or factors present on a chromosome are inherited together except when crossing over takes place. The phenomenon of inheritance of a number of genes or factors due to their occurrence together on the same chromosomes is called **linkage**. The linkage is exception to law of independent assortment.

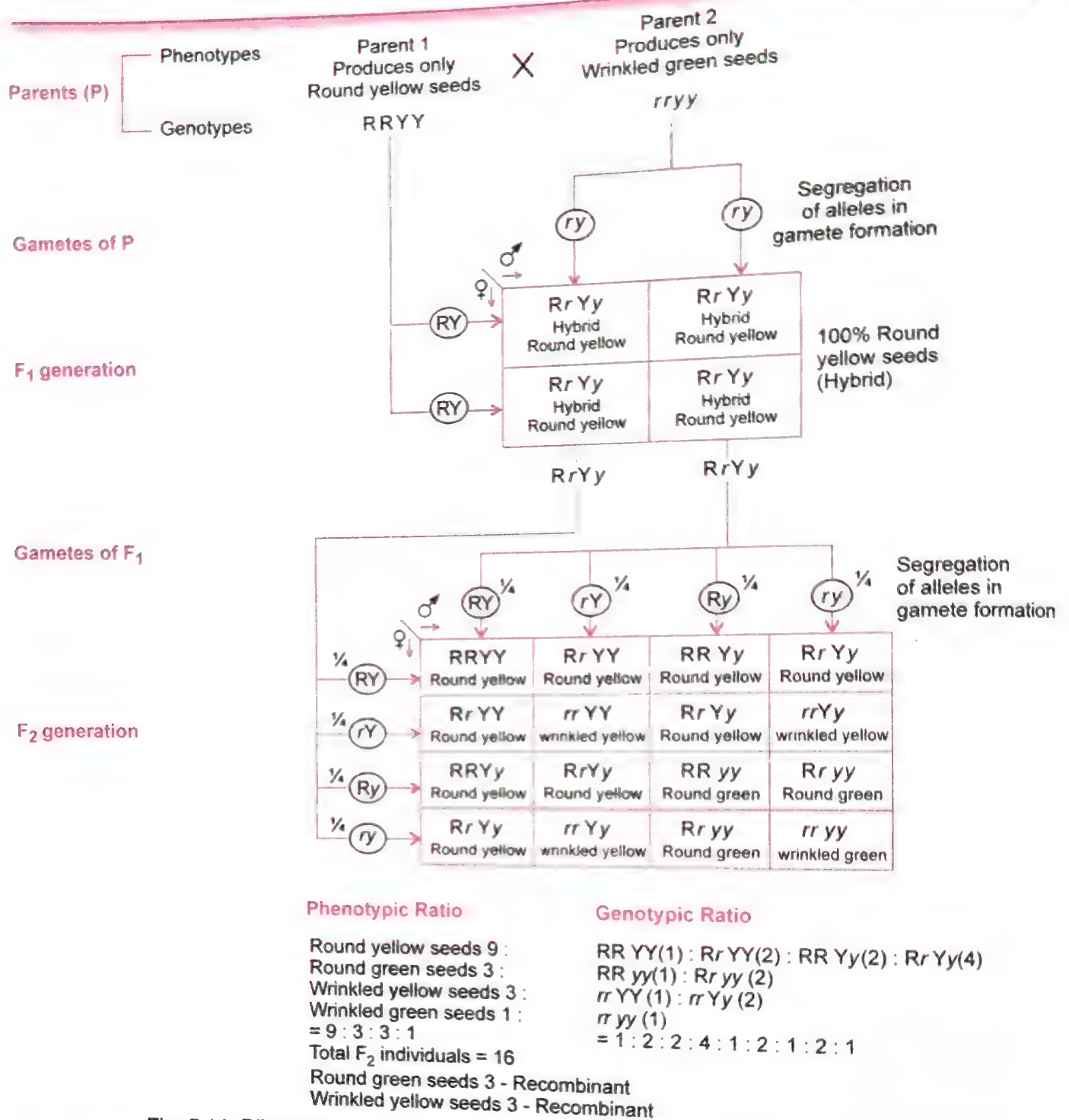


Fig. 5.14. Dihybrid cross in pea plants showing law of independent assortment.

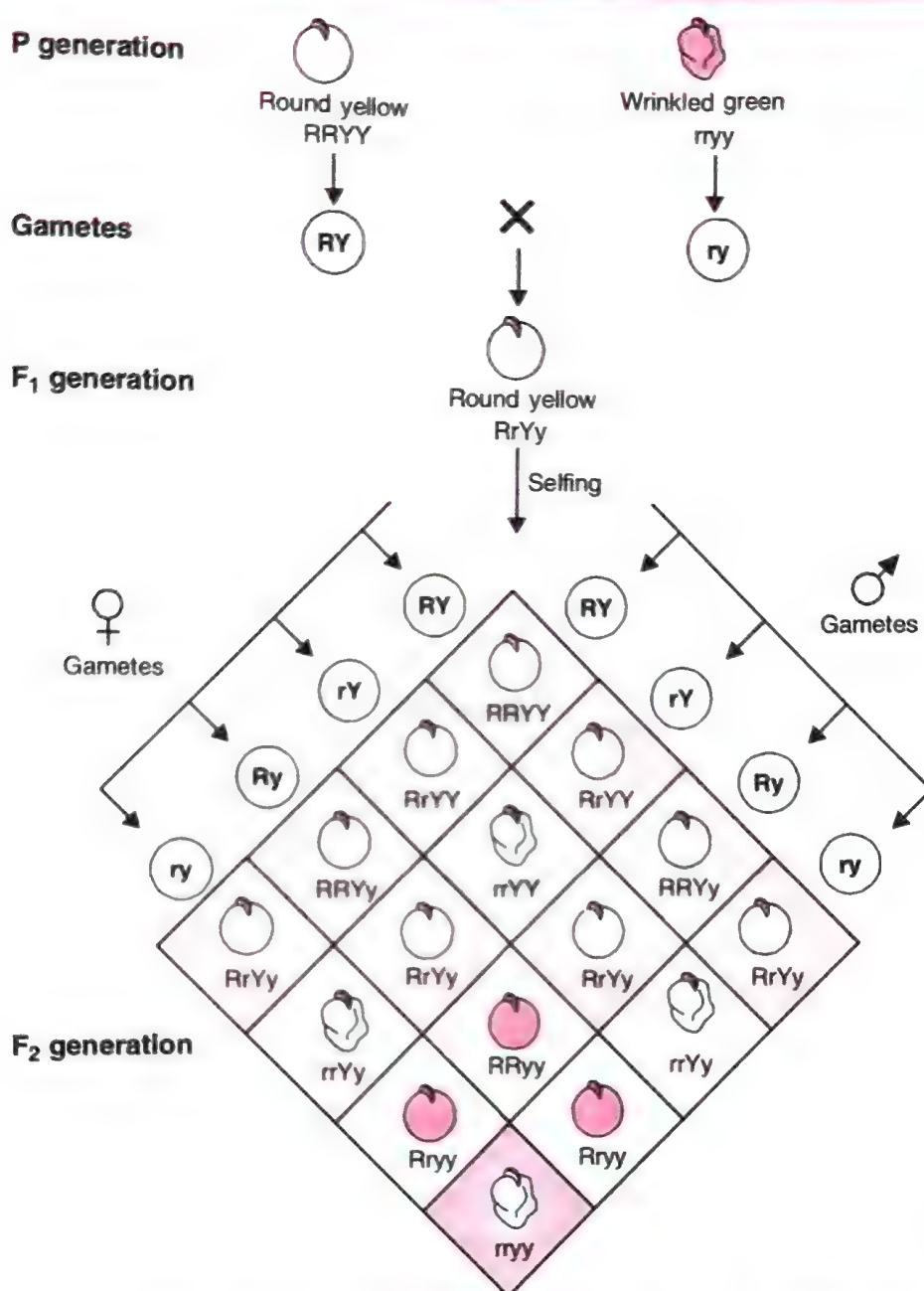
Limitations of Mendelism

Mendelism has certain limitations. Idea of paired factors (alleles), *i.e.*, each trait is controlled by atleast two alleles, is not universally applicable. A single gene called **pleiotropic gene** controls the expression of a number of traits.

Similarly, a single trait may be controlled by more than two alleles of a gene, called **multiple alleles**.

Though law of dominance is applicable to a large number of characters but it does not have universal application. **Incomplete dominance** and **co-dominance** are exceptions to law of dominance. The law of segregation is universally applicable but the law of independent assortment does not apply to linked genes (**linkage**).

The dihybrid cross in pea plants (Fig. 5.14) can also be shown as follows.



Phenotypic Ratio : Round Yellow : Round Green : Wrinkled Yellow : Wrinkled Green

9 : 3 : 3 : 1

Genotypic Ratio : 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1

Fig. 5.15. Results of a dihybrid cross where the two parents differed in two pairs of contrasting traits : seed colour and seed shape.

Differences between Monohybrid and Dihybrid Cross

Monohybrid Cross	Dihybrid Cross
1. It is a cross between two pure organisms in order to study the inheritance of a single pair of alleles.	1. It is a cross between two pure organisms of a species in order to study the inheritance of two pairs of alleles.
2. It produces a phenotypic monohybrid ratio of 3 : 1 in F ₂ generation.	2. It produces a phenotypic dihybrid ratio of 9 : 3 : 3 : 1 in F ₂ generation.
3. It produces genotypic ratio of 1 : 2 : 1 in F ₂ .	3. It produces genotypic ratio of 1 : 2 : 1 : 2 : 4 : 2 : 1 : 2 : 1

POST -- MENDELIAN DISCOVERIES

(Genetic Principles Discovered After Mendel)

GENE INTERACTION

Gene interaction is the influence of one allele over another of the same or other gene. It is of two types, **interallelic (intragenic)** and **nonallelic (intergenic)**. In the interallelic interaction the influence of one allele over another allele of the same gene, e.g., incomplete dominance, codominance, multiple alleles, lethal genes. In nonallelic interaction, allele of one gene influences the expression of another gene, e.g., epistasis, duplicate genes, complementary genes, supplementary genes.

INTERALLELIC (INTRAGENIC) INTERACTION

Incomplete Dominance (Intermediate Inheritance, 1 : 2 : 1 Ratio)

Incomplete dominance is the phenomenon where none of the two alleles of a gene is dominant over each other so that when both of them are present together, a new phenotype is formed which is somewhat intermediate between the independent expression of the two alleles.

It is also called mosaic or intermediate or blending inheritance. Incomplete dominance was discovered by **Carl Correns** in 1903. Incomplete or mosaic inheritance is not an example of pre-mendelian concept of blending inheritance because the parental types reappear in the F_2 generation. It is however, considered by some workers to be an example of quantitative inheritance where only a single gene pair is involved. F_2 phenotypic ratio is 1:2:1, similar to genotypic ratio.

Examples. (i) Flower colour in Snapdragon and Four O'Clock. In *Antirrhinum majus* (Snapdragon or Dog flower) and *Mirabilis jalapa* (Four O' Clock), there are two types of flower colour in pure state, red and white. When the two types of plants are crossed, the hybrids or plants of F_1 generation have pink flowers (Figs. 5.16 & 5.17). If the latter are selfed, the plants of F_2 generation are of three types— red, pink and white flowered in the ratio of 1 : 2 : 1. The pink colour apparently appears either due to

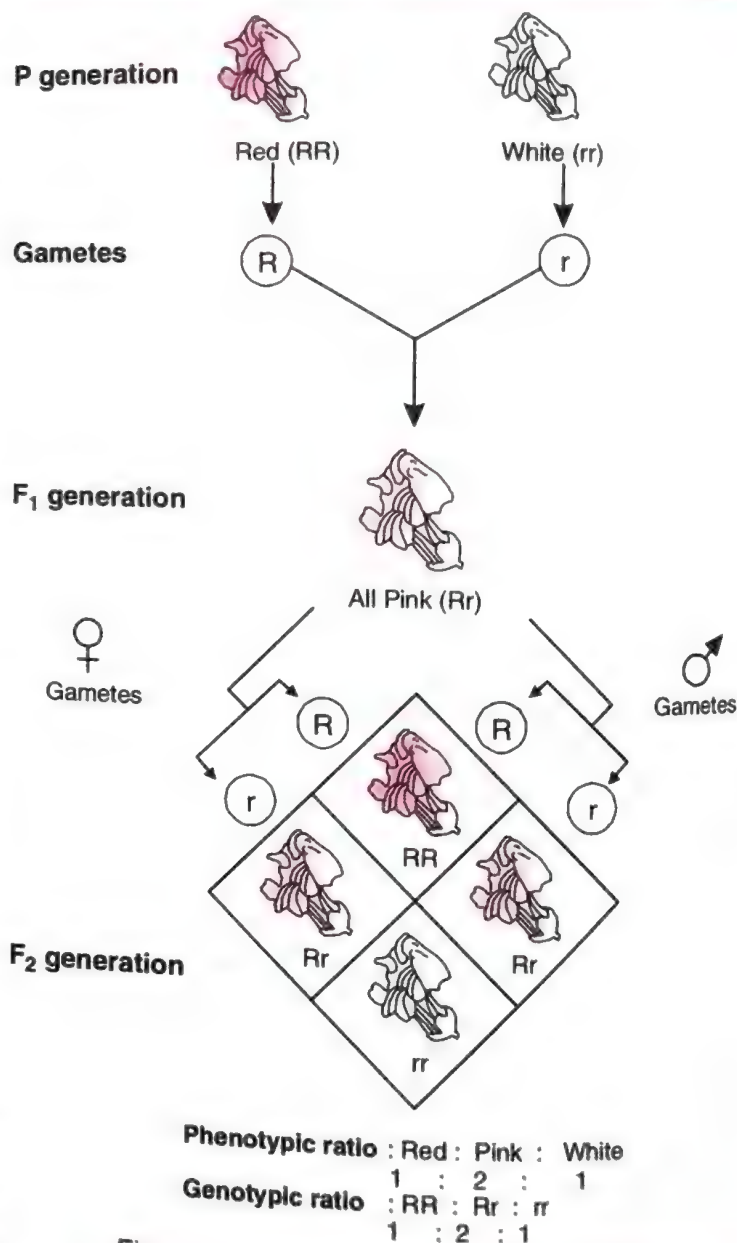


Fig. 5.16. Incomplete dominance in *Snapdragon*.

mixing of red and white colours (incomplete dominance) or expression of a single gene for pigmented flower which produces only pink colour (quantitative inheritance).

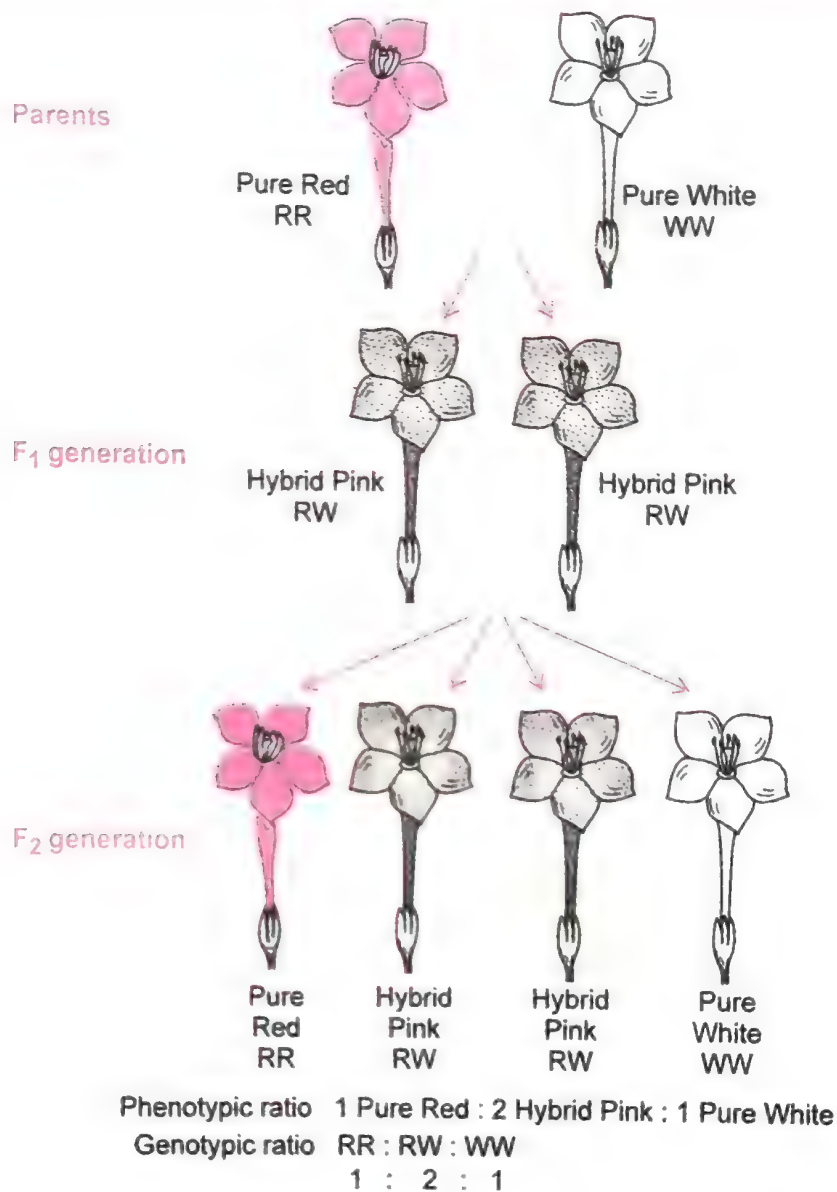


Fig. 5.17. Incomplete dominance in *Mirabilis jalapa* (Four O'clock).

(ii) **Andalusian Fowls** (Fig. 5.18). They have two pure forms, black and white. If the two forms are crossed, F₁ individuals appear blue coloured due to occurrence of fine alternate black and white stripes on the feathers. Incidentally the blue coloured fowls are favoured as delicacy. F₂ generation produces three types of fowls— 1 black : 2 blue : 1 white.

Explanation of the Concept of Dominance. Every gene, contains the information to express a particular trait. In a diploid organism, there are two copies of each gene (a pair of alleles). Now, these two alleles need not always be identical, as in a heterozygote. One of them may be different due to some changes that it has undergone which modifies the information that particular allele contains.

Take an example of a gene that contains the information for producing an enzyme. Now there are two copies of this gene, the two allelic forms. Let us assume that the normal allele

produces the normal enzyme that is needed for the transformation of a substrate S. Theoretically, the modified allele could be responsible for production of (i) the normal/less efficient enzyme, or (ii) a non-functional enzyme or (iii) no enzyme at all.

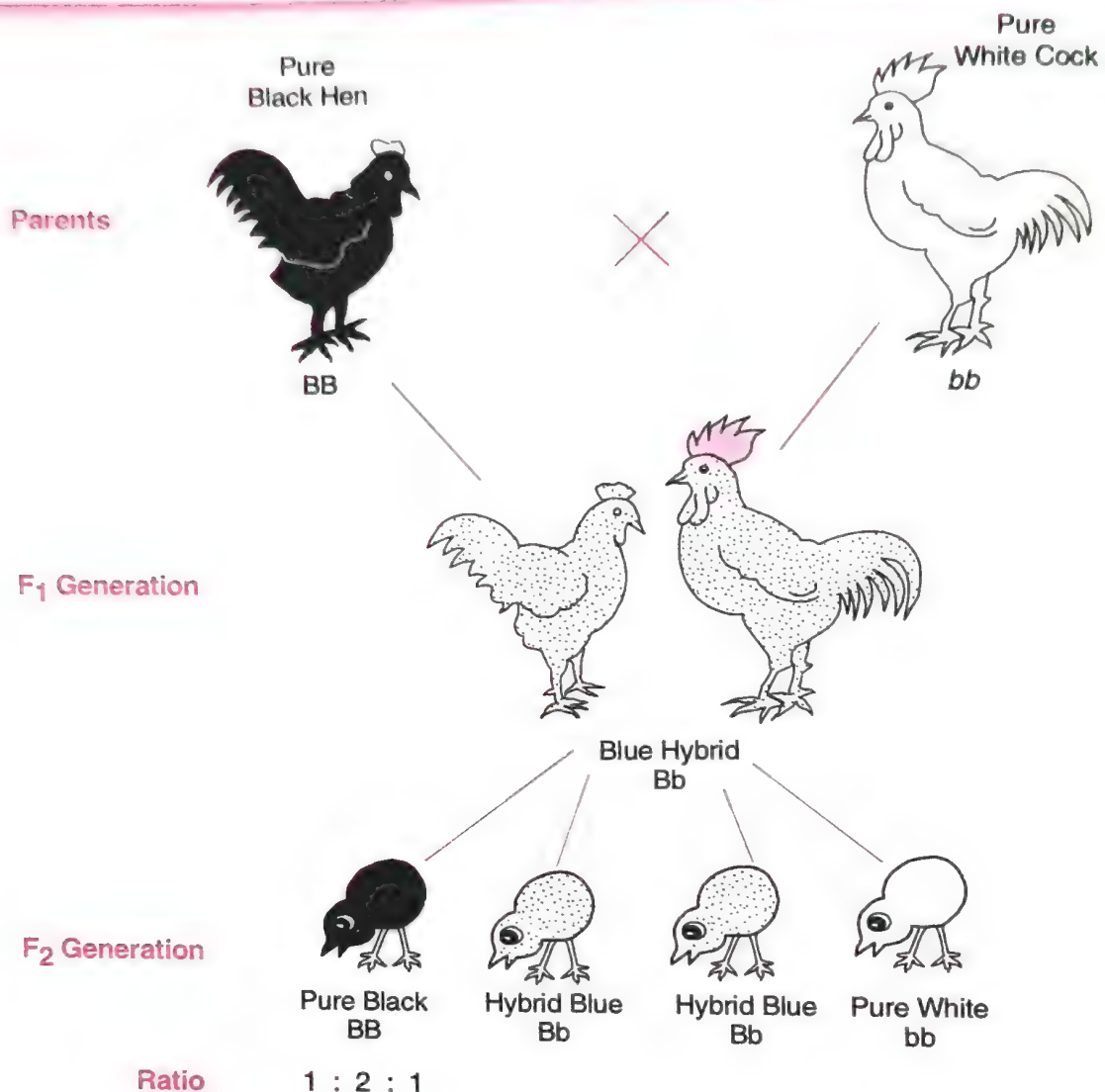


Fig. 5.18. Incomplete dominance in Andalusian Fowl.

In case (i), the modified allele is equivalent to the unmodified allele, *i.e.*, it will produce the same phenotype/trait as in case of silent mutation. But, if the allele produces a non-functional enzyme or no enzyme [case (ii) and (iii)], the phenotype may be effected. The **unmodified (functioning) allele**, which represents the original phenotype is the **dominant allele/wild type** and the **modified allele** is generally the **recessive allele/mutant type**. Hence, the recessive trait is due to non-functional enzyme or because no enzyme is produced. Let us take the example of tallness. Plant height depends on the amount of particular plant hormone. The amount of the plant hormone made will depend on the efficiency of the process for making it. If an enzyme that is important for this process, works efficiently, a lot of hormone will be made, and the plant will be tall. If the gene for that enzyme has an alteration that makes the enzyme non-functional or no enzyme at all, the amount of hormone will be less and the plant will be dwarf.

Dominance as product of a Particular Phenotype. The gene for starch synthesis in Pea seeds can produce more than one effect. It has two alleles **B** and **b**. In **BB** genotypes,

large starch grains are produced. After maturation the seeds are round. In **bb** homozygotes, smaller starch grains are produced. The mature seeds are wrinkled. **Bb** heterozygotes form round seeds so that **B** seems to be dominant allele. However, **Bb** seeds have starch grains of intermediate size. If size of starch grains is considered as phenotype, **Bb** alleles show incomplete dominance. Therefore, dominance is not the feature of gene or its product. It depends upon the gene product and particular phenotype we choose to examine when a gene produces more than one phenotype.

Differences between Dominant and Incomplete Dominance	
Dominance	Incomplete Dominance
1. F_1 is similar to the dominant parent.	1. F_1 is different from either of the two parents.
2. Phenotypic ratio is different from genotypic ratio.	2. Phenotypic and genotypic ratios are the same.
3. In F_1 hybrid, the dominant trait is completely expressed.	3. In F_1 hybrid, dominant trait is incompletely expressed.
4. A single dominant allele (e.g., Tt) expresses fully.	4. Two alleles (e.g., RR) are required for the expression of complete dominant trait.

Codominance (1 : 2 : 1 Ratio)

When both the alleles of a gene express themselves simultaneously in a heterozygote, this condition is called codominance.

Both the alleles which are present together in heterozygous individual but neither show dominant – recessive relationship nor show intermediate condition but express their traits independently are known as **codominant alleles**.

Codominant alleles should not be confused with incomplete dominance. In the latter case the effect of one of the alleles is more pronounced. The symbols used for codominant alleles are different. Here the codominant alleles are shown by the same capital letter with different superscripts, e.g., I^A , I^B , Hb^A , Hb^S . Another method is to show them by their own capital alphabets, e.g., R (for red hair) and W (for white hair in cattle).

Example 1. AB Blood Group. To understand this example, let us share some informations about human ABO blood group.

(i) ABO blood group in human beings comprises four blood groups. Blood group A, B, AB and O. Three blood groups A, B and O were discovered by **Landsteiner** (1900) while one blood group AB was discovered by **de Castello** and **Steini** (1902).

(ii) The plasma membrane of human RBCs has glycoproteins called **antigens** or **agglutinogens** or **isoagglutinogens**. The type of antigen is controlled by gene I. The gene I has three alleles I^O , I^A and I^B . Both alleles I^A and I^B are dominant to allele I^O but are themselves codominant.

(iii) Allele I^O does not produce any surface antigen. Allele I^A produces antigen A. Allele I^B produces antigen B.

(iv) In every person, any two of the three alleles may be present. Refer to the following table. The letter 'I' is used to designate the allele which is derived from isoagglutinin or letter 'L' after the name of Landsteiner.

Blood Groups (Phenotype), their Genotypes and Antigens

Blood Group (Phenotype)	Genotype	Antigen on RBCs	Nature
O	$I^O I^O$	None	Recessive
A	$I^A I^A$ or $I^A I^O$	A	Dominant
B	$I^B I^B$ or $I^B I^O$	B	Dominant
AB	$I^A I^B$	AB	Codominant

(a) Persons with $I^O I^O$ alleles have **blood group O** because they neither have antigen A nor antigen B.

(b) Persons with $I^A I^A$ or $I^A I^O$ alleles have **blood group A** because allele I^A is dominant on allele I^O .

(c) Persons with $I^B I^B$ or $I^B I^O$ alleles have **blood group B**.

(d) Persons with $I^A I^B$ alleles have **blood group AB** because both I^A and I^B alleles are codominant.

ABO blood grouping is also an example of **multiple alleles** because three alleles govern the same character. However, all cases of multiple allelism do not show codominance.

Therefore, *alleles for blood group A (I^A) and blood group B (I^B) are codominant so that when they come together in an individual, they produce blood group AB*. It is characterised by the presence of both antigen A (from I^A) and antigen B (from I^B) over the surface of RBCs.

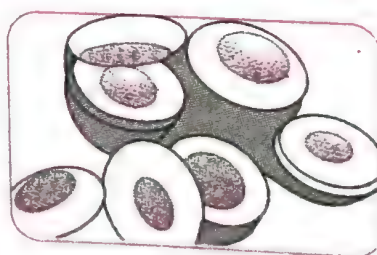
Example 2. MN Blood Group. Landsteiner and Levine in 1927 discovered MN blood group system. In MN blood group system antigens **M** and **N** are present on the surface of RBCs but antibodies are absent. Three types of blood groups are found : M, N and MN. Antigen M is present in case of M group, N in case of N group and both M and N in case of MN blood group.

Blood groups (phenotype), genotype and antigens

Blood Group (Phenotype)	Genotype	Antigen Present on RBCs	Antibodies
M	MM	M	None
N	NN	N	None
MN	MN	MN	None

Persons with M and N blood groups are homozygous, MM and NN respectively and people with MN blood group are heterozygous as shown in the table. Therefore, it is evident that *M and N genes are codominant*.

MN blood group does not have any significance in blood transfusion. But it is helpful in solving disputed parentage and identity of blood stains in forensic science.



A



B

Fig. 5.19. A. RBCs of a normal person. B. RBCs of a person suffering from sickle cell anaemia.

Example 3. Sickle Cell Haemoglobin. Sickle-cell anaemia is a hereditary disease found in tropical Africa but is now spreading in American blacks whose ancestors came from that part of Africa. In India it is found in some parts of Kerala. Persons suffering from sickle cell anaemia have **sickle cell haemoglobin (Hb^S)** in their RBCs. Such RBCs become sickle - shaped under low oxygen concentration.

In fact the disease sickle cell anaemia is caused by a gene Hb^S . Its normal allele is Hb^A which produces normal haemoglobin.

Persons with $Hb^A Hb^A$ genotype have normal haemoglobin but the persons with $Hb^S Hb^S$ have sickle cell haemoglobin. They die of **lethal or fatal anaemia** but heterozygous persons with $Hb^A Hb^S$ genotype have both types of haemoglobin and suffer from mild anaemia because some of their RBCs during oxygen deficiency, become sickle shaped. It shows that Hb^A and Hb^S genes are **codominant**.

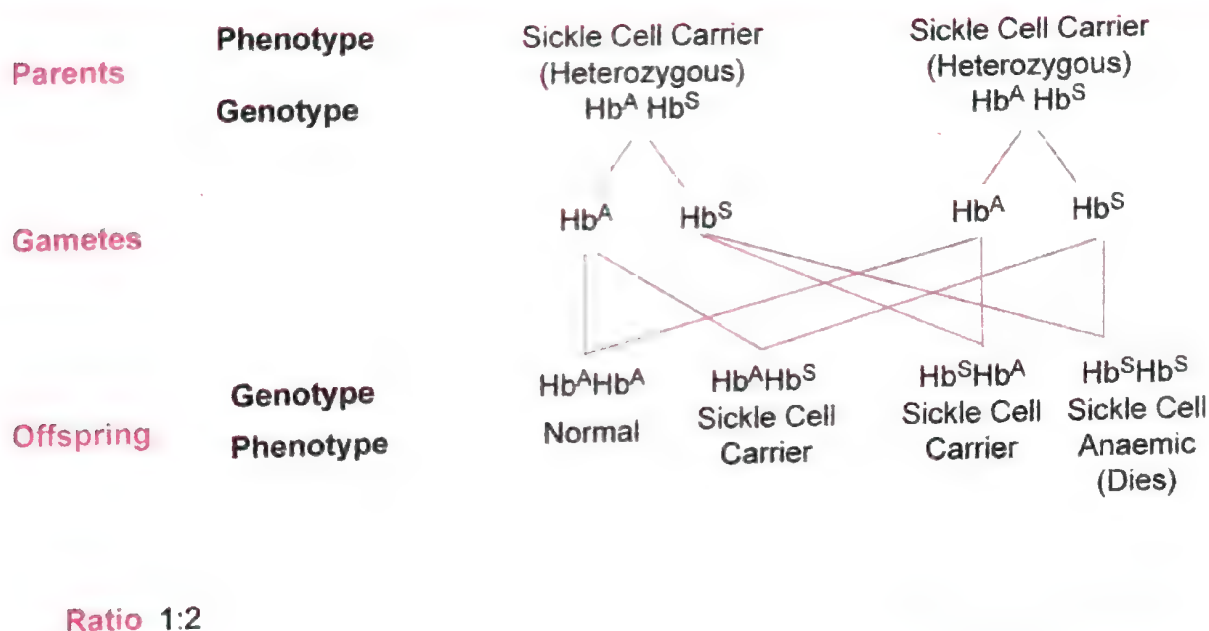


Fig. 5.20. Inheritance of Sickle-Cell trait.

[As per NCERT book sickle cell anaemia is considered as autosomal recessive trait.]

Example 4. Coat* Colour in Cattle.** In cattle gene R stands for red coat colour and gene W for white coat colour. When Red Cattle (RR) are crossed with white cattle (WW), the hybrids of the F_1 generation are of roan*** colour with genotype RW. The roan colour in cattle comprises dark colour (red) interspersed with white colour which develop side by side in heterozygous organisms. In F_2 generation red, roan and white cattle are produced in the ratio of 1 : 2 : 1 (1 RR : 2 RW : 1 WW).

Roan colour cattle are heterozygous which shows here that R gene and W gene are codominant.

*Coat — an animal's covering of hair or fur.

**Cattle — cows, bulls and oxen (pl. of ox). Oxen are castrated bulls used for pulling heavy loads.

Roan*** (of cattle) having a dark coat interspersed with white hair (CHITKABRA in Hindi).

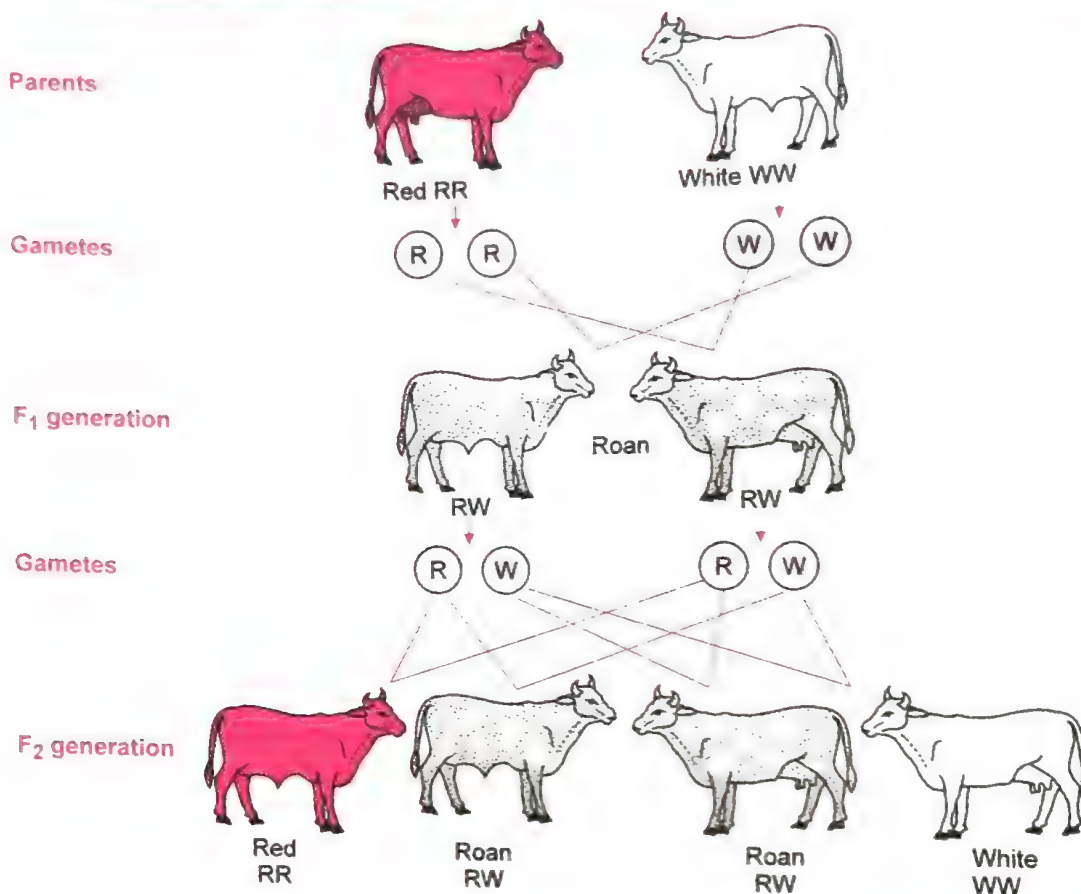


Fig. 5.21. Inheritance of coat colour in cattle.

Differences between Incomplete Dominance and Codominance

Incomplete Dominance	Codominance
<ol style="list-style-type: none"> 1. Effect of one of the two alleles is more conspicuous. 2. It produces a fine mixture of the expression of two alleles. 3. The effect in hybrid is intermediate of the expression of the two alleles. 4. The hybrid possesses a new phenotype. 5. The expressed new phenotype has no allele of its own. 6. The incomplete dominance is the result of quantitative effect of alleles. 	<ol style="list-style-type: none"> 1. The effect of both the alleles is equally conspicuous. 2. There is no mixing of the effect of the two alleles. 3. Both the alleles produce their effect independently, e.g., I^A and I^B, Hb^S and Hb^A. 4. A new phenotype does not develop. 5. The expressed phenotype is combination of two phenotypes and their alleles. 6. A quantitative effect is absent.

Differences between Codominance and Dominance

Codominance	Dominance
<ol style="list-style-type: none"> 1. Both the alleles are equally dominant. 2. Both the alleles show their independent effects even in heterozygous condition. 3. The number of phenotypes is one more than the number of alleles. 	<ol style="list-style-type: none"> 1. Only one allele is dominant. 2. Only one allele shows its independent effect in heterozygous condition. 3. The number of phenotypes is the same as the number of alleles.

Multiple Alleles

More than two alternative forms (alleles) of a gene in a population occupying the same locus on a chromosome or its homologue are known as multiple alleles.

Mode of Origin. Multiple alleles are produced due to repeated mutation of the same gene but in different directions. Multiple alleles show meristic type of germinal variations. Meristic variation involves the number or arrangement of the parts. Thus meristic (Gr. *meristos* – divisible, *meros* – part) variations cause multiple alleles.

Characteristics. (i) There are more than two alleles of the same gene, e.g., 15 alleles for eye colour in *Drosophila*, 3 alleles for blood groups in humans, 4 alleles for coat colour in rabbit. (ii) All of them are mutants of the same wild allele. (iii) All the multiple alleles of the gene occur on the same gene locus of the same chromosome or its homologue. (iv) An individual possesses only two alleles of a gene. (v) A gamete or a chromosome carries only one allele of the group. (vi) Multiple alleles express different alternatives of a single trait. (vii) Different alleles may show codominance, dominance-recessiveness or incomplete dominance among themselves. (viii) Multiple alleles follow Mendelian pattern of inheritance.

Example 1. Human ABO Blood Groups. The human blood groups illustrate both multiple alleles and codominance. But all cases of multiple alleles do not show codominance.

There are ABO groups in human beings — A, B, AB and O. These letters refer to a glycoprotein substance called an **antigen** present on the surface of RBCs.

People with blood group A form antigen A, those with blood group B produce antigen B, those with blood group AB form both antigen A and antigen B and those with blood group O produce no antigen.

ABO blood groups are controlled by the gene *I* (also called *L*) located on 9th chromosome that has 3 multiple alleles, I^A , I^B and I^O , out of which any two are found in a person. Presence, absence and type of antigens are determined by three immunogen alleles I^A , I^B and I^O . I^A forms antigen A, I^B antigen B while allele I^O is recessive and does not form any antigen. Both I^A and I^B are dominant over I^O , but not over each other. When both I^A and I^B are present in a person, both the alleles are able to express themselves forming antigens A and B. Such alleles which are able to express themselves in the presence of each other are called codominant. Thus blood group alleles show both codominant and dominant-recessive relationships ($I^A = I^B > I^O$).

A human being carries two of the three alleles, one from each parent. The maximum number of possible genotypes is six for the four phenotypes. The phenotypes are tested by two antisera, anti-A and anti-B.

Table 5.6. Human ABO Blood Groups

Genotype	Phenotype
$I^A I^A$ or $I^A I^O$	A
$I^B I^B$ or $I^B I^O$	B
$I^A I^B$	AB
$I^O I^O$	O

Blood Groups (Phenotype)	Genotype	Antigen on RBCs	Anti body in Plasma	Reaction with		Approximate Percentage in India
				Anti-A	Anti-B	
A	$I^A I^A$, or $I^A I^O$	A	b	+	—	22
B	$I^B I^B$ or $I^B I^O$	B	a	—	+	33
AB	$I^A I^B$	A and B	None	+	+	5
O	$I^O I^O$	None	a and b	—	—	40

Determination of the ABO blood Groups. The determination of ABO blood groups is also called Blood grouping or Blood typing. One drop of Antiserum A is placed on one end of glass slide and one drop of Antiserum B on the other end. One drop of blood containing RBCs is mixed with each serum. The slide is slightly moved for 2 minutes. The presence or absence of agglutination (clumping) is observed by naked eyes or under microscope. **Clumping** : Thick masses of RBCs are seen. **Absence of clumping** : The mixture is clear with separate cells. If agglutination occurs with antiserum A, the blood group is A, if agglutination occurs with antiserum B, the blood group is B, if agglutination occurs with both antiserum A and antiserum B, the blood group is AB and if agglutination does not occur either with antiserum A or antiserum B, the blood group is O.

Inheritance of Human ABO Blood Groups. Inheritance of A, B, AB and O blood groups in human beings was discovered by **Bernstein** in 1925. As stated earlier the alleles I^A and I^B are dominant over allele I^O but are codominant to each other and both are expressed when present together.

(i) When a man homozygous for blood group A marries a woman with blood group O or vice versa, all their children will have blood group A.

(ii) If a man homozygous for blood group B marries a woman with blood group O or vice versa, all their children will have blood group B.

(iii) When a man homozygous for blood group A marries a woman homozygous for blood group B or vice versa all their children may have blood group AB.

(iv) When a man heterozygous for blood group A marries a woman heterozygous for blood group B, their children may have all the four blood groups A, B, AB or O.

(v) If a man with blood group AB marries a woman with blood group AB, their children may have A, B or AB blood groups.

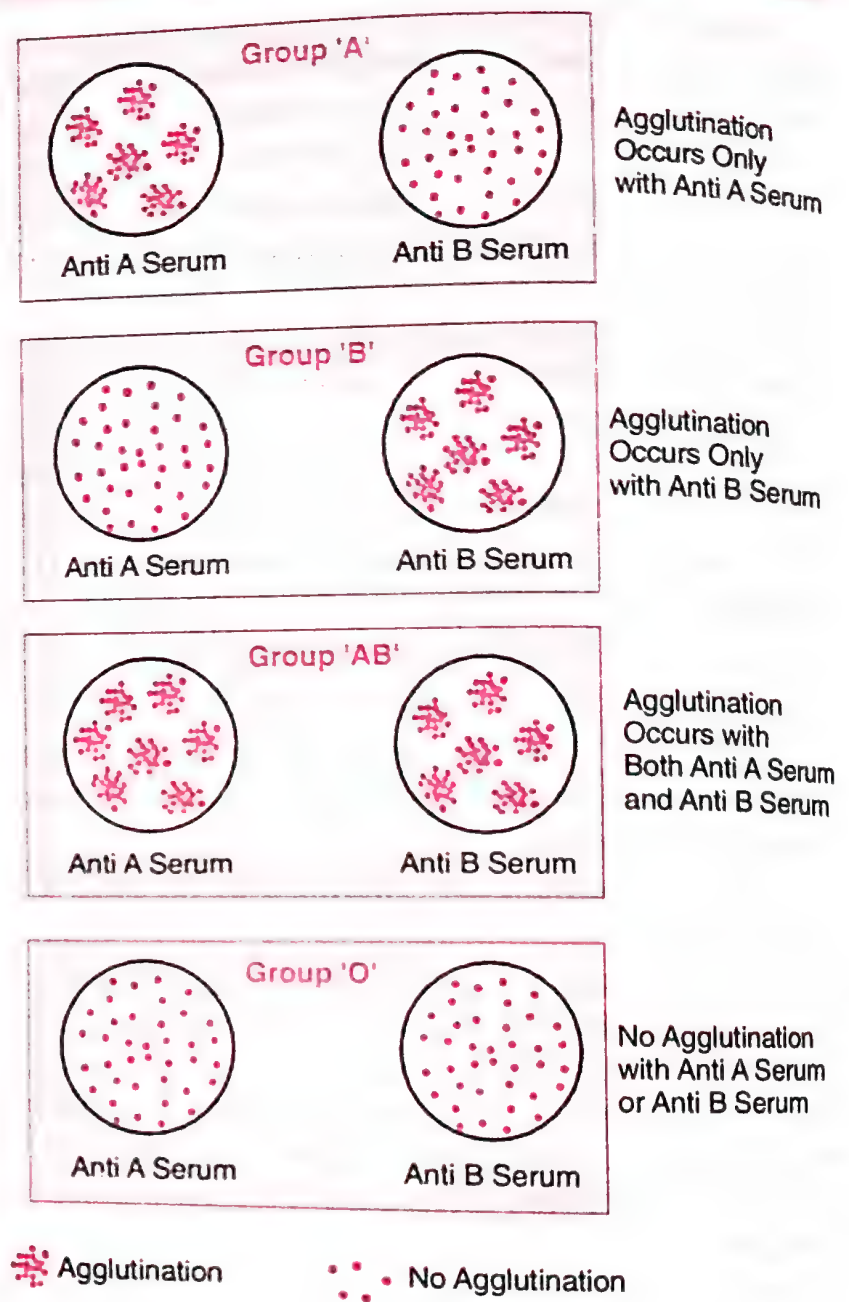


Fig. 5.22. Determination of ABO blood groups with Anti A serum and Anti B serum.

Table 5.6. Blood Groups of Parents and their Offspring

S.No.	Parents	Offspring	Not Possible
1.	O × O	O	A, B, AB
2.	O × A	O, A	B, AB
3.	A × A	O, A	B, AB
4.	O × B	O, B	A, AB
5.	B × B	O, B	A, AB
6.	A × B	O, A, B, AB	—
7.	O × AB	A, B	O, AB
8.	A × AB	A, B, AB	O
9.	B × AB	A, B, AB	O
10.	AB × AB	A, B, AB	O

Blood Transfusion. Blood transfusion is best between persons of the same blood groups, but some inter-blood group transfusion can also be safely done if necessary.

Since the RBCs of the persons of 'O' blood group have no blood group antigens, the blood of these persons can be donated to persons of all blood groups. Therefore, persons of 'O' blood group are called **universal donors**. The persons of AB blood group have both antigens A and B in their RBCs but no antibodies in their plasma, such persons cannot donate blood to persons of other blood groups but can receive blood from all other persons, hence they are called **universal recipients**.

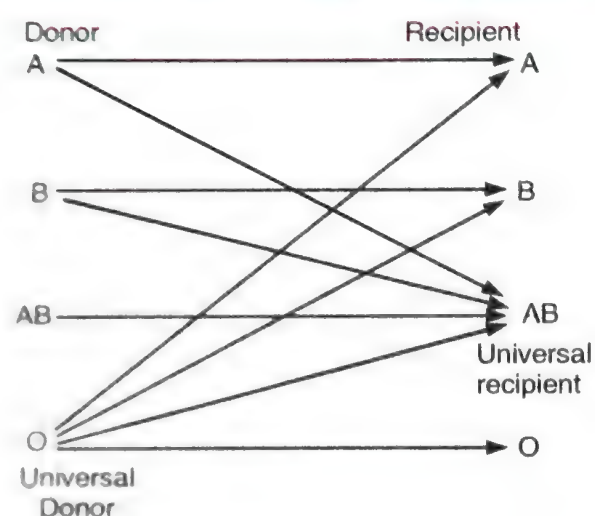


Fig. 5.23. Diagrammatic representation of compatible blood transfusion.

Table 5.7. Blood Transfusion Compatibilities for the ABO Blood Groups

Blood Group	Terminal Sugars of Antigens Present	Antibodies Present	Red Cell Types Agglutinated	Transfusions Accepted From
A	A (galactosamine)	Anti B or b	B, AB	A or O
B	B (galactose)	Anti A or a	A, AB	B or O
AB	A (galactosamine) and B (galactose)	None	None	A, B, AB or O
O	None	Anti A or a and anti B or b	A, B and AB	O

Biochemical Basis of ABO Blood Groups. Antigens of ABO blood groups are protein-sugar compounds (mucopolysaccharides). According to **Kabat, Watkins** and others, the antigens are carbohydrate groups (polysaccharides) that are bound to the **lipid** molecules of the membrane of RBCs. The antigen A and antigen B differ only in terminal sugar molecule of carbohydrate group. (i) In **antigen A**, the terminal sugar of carbohydrate chain is a modified monosaccharide-**N-acetyl- α -D galactosamine**. In this, N-acetyl group is attached

at No. 2 position of terminal galactose sugar. (ii) In **antigen B**, the terminal carbohydrate sugar is unmodified monosaccharide α -D-galactose. In this the No.2 position in galactose sugar is occupied by hydroxyl group.

Almost all individuals possess **H substance** (antigenic precursor H) in RBC membrane. H-substance is formed of three monosaccharides — N-acetyl glucosamine, galactose and fucose. Antigen A and antigen B are derived from this H-substance by the addition of terminal galactose sugar.

This explains why A and B alleles are dominant to I^O and are codominant. Therefore, persons with both alleles I^A and I^B have both the antigens. The recessive gene action is, therefore, a result of absence of enzyme. In heterozygous condition, the functional gene I^A or I^B masks the effect of non-functional I^O gene.

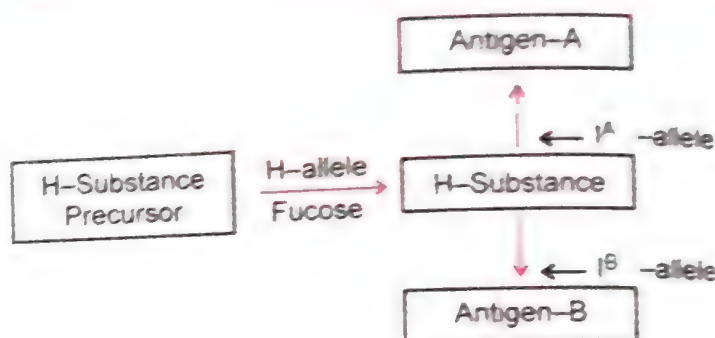


Fig. 5.24. Chemistry of formation of antigen A and antigen B.

Importance of ABO Blood Groups. (i) They are helpful in solving cases of **disputed parentage**. (ii) The knowledge of ABO blood groups is also useful in settling **cases of illegitimacy** (incident where child is born to parents not married to each other). (iii) Blood tests can be used to solve **cases of claimants** to estates or in certain kinds of criminal proceedings.

Example 2. Eye colour in Fruit fly-*Drosophila*. Eye colour in *Drosophila* is controlled by 15 multiple alleles. The normal or wild type eye colour is red represented by allele W or w. There is an allele w for white eye colour which is recessive to all other alleles. Alleles of other eye colour traits are intermediate between the two. They show various types of codominance and incomplete dominance. These important alleles are w^{ch} (cherry), w^i (ivory white), w^{co} (coral), w^{bf} (buff), w^h (honey), w^{bl} (blood), w^{eo} (eosine), w^w (wine), w^p (pearl), etc.

Example 3. Coat colour in Rabbits. In rabbits coat colour is represented by 4 alleles—C, C^h , C^{ch} and c. The coat of rabbit may have following different colours.

(i) **Agouti Type Coat.** The coat of the ordinary (wild type) rabbit is referred to as “**agouti**” or **full colour**. It has dark brown and uniform colour. The gene for full colour is represented by capital letter C.

- Agouti is a brown large long legged burrowing rodent related to the guinea pig. It is a native of Central and South America.

(ii) **Chinchilla Type Coat.** The coat is silvery-gray and uniform in colour. The gene for chinchilla is represented as C^{ch} .

- Chinchilla is a small South American rodent.

(iii) **Himalayan Type Coat.** This type of coat is white except extremities (nose, ears, feet and tail). The gene for Himalayan coat is represented by C^h .

(iv) **Albino Type Coat.** The albino coat totally lacks in pigmentation. The eyes of an albino also remain pink due to lack of pigment in iris of eye. The gene for albino is represented by c.

Albino (*L. albus* – white) colourless — absence of pigment in skin, hair and eyes.

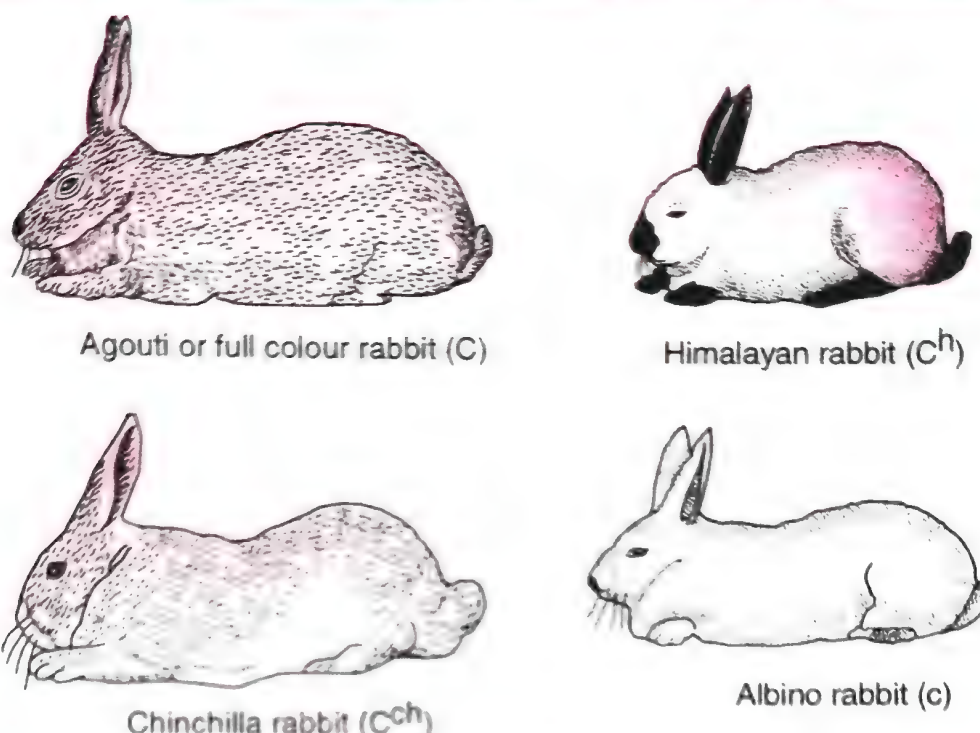


Fig. 5 25 Different coat colour in rabbits.

The gene **C** for full colour is dominant over all other alternatives. Chinchilla (C^{ch}) is recessive to full colour but dominant to others (Himalayan and albino). Himalayan (C^h) is recessive to full colour and chinchilla but is dominant over albino. The different phenotypes and their genotypes are as follows :

Coat Colour in Rabbit

Phenotype	Genotype
Agouti (Full colour)	CC, CC ^{ch} , CC ^h , Cc
Chinchilla	C ^{ch} C ^{ch} , C ^{ch} C ^h , C ^{ch} c
Himalayan	C ^h C ^h , C ^h c
Albino	cc

Lethal Genes (2 : 1 Ratio)

A lethal gene can be defined as a gene whose phenotypic effect is sufficiently drastic to kill the bearer. The normal segregation ratio is modified into 2 : 1 ratio.

Types of Lethal Genes. Lethal genes are of three types — dominant, recessive and conditional.

(i) **Dominant Lethal Genes.** The dominant lethal genes are lethal in homozygous condition and produce some defective or abnormal phenotype in heterozygous condition. Dominant lethal genes can not be transmitted to next generation, because the individuals

carrying these genes die. They are lost in the same generation. **Examples.** (a) Lethal gene was first discovered by Cuenot (1905) in mouse body colour. (b) **Brachyphalangy** (short fingers) in humans. (c) Inheritance of **sickle-cell anaemia** in man. (d) **Huntington's Chorea in man** (the person suffers from muscular failure, mental retardation and finally death).

(ii) **Recessive Lethal Genes.** The recessive lethal genes produce lethal effect only in homozygous condition. Their heterozygotes are normal. Recessive lethal genes are carried in heterozygous condition. **Examples.** (a) **Tay Sach's disease** — accumulation of fat in nerve sheaths hampers transmission of nerve impulse leading to poor muscular control and mental deficiency. (b) **Hydrocephaly in mice** — irregularly formed skull and brain and accumulation of cerebrospinal fluid. (c) **Albinism in corn** — A lethal gene in corn. The non-chlorophyll plants are unable to manufacture their own food and will die as soon as food stored in the grain has been consumed.

(iii) **Conditional Lethal Genes.** The genes which may be normal to the individual in a particular environment may prove to be lethal when environment is changed. **Example.** In **poultry** a recessive gene causes feathers to break off. The chickens homozygous for this gene are featherless. If these are kept in relatively warm environment, they survive but if temperature falls below optimum, the featherless chickens die.

- Soon after Cuenot's discovery in mouse, **E. Baur** (1907) reported a lethal gene in Snapdragon, *Antirrhinum majus*.

- **Thalassemia major** is also one of the best known example of lethal genes. This disease of humans is characterized by severe anaemia, enlargement of the heart, leg ulcers, etc.

NONALLELIC (INTERGENIC) INTERACTIONS

Alleles of two or more independent genes interact to produce a phenotypic expression different from normal expression.

Salient Features of Nonallelic (Intergenic) Gene Interaction

The characteristics of such nonallelic interactions are as follows.

1. Interaction produces a distinct phenotype different from the normal.
2. Interacting genes show normal dominance–recessiveness and assort independently.
3. At phenotypic level, homozygotes and heterozygotes, such as AA or Aa and BB or Bb show their respective phenotypes governed by the dominant alleles. They are designated as A– or B–, where a dash indicates the presence of either allele.
4. The F₁ individuals are heterozygous for the various gene pairs (Aa Bb) which will be selfed or intercrossed.
5. In a normal dihybrid cross, the F₂ genotypes fall into four phenotypic classes 9/16 A– B–, 3/16 A–bb, 3/16 aa B– and 1/16 aabb.

Epistasis

Epistasis (Gk. *epi* — above, *stasis* — standing) is the phenomenon of masking or suppressing the expression of a gene by another nonallelic gene. The gene which suppresses the expression of a nonallelic gene is known as **epistatic gene**. The gene or locus which is suppressed by the presence of nonallelic gene is termed as **hypostatic gene**. The phenomenon by which the effect of a gene gets suppressed due to the presence of a nonallelic gene is called **hypostasis**.

Types of Epistasis. Epistasis is of two types — dominant and recessive.

(i) **Dominant Epistasis (12 : 3 : 1 Ratio).** In this condition, the epistatic gene is dominant over its own allele. It is therefore, effective even in heterozygous condition. The dihybrid ratio for dominant epistasis is 12 : 3 : 1. **Example :** Fruit colour in *Cucurbita pepo* (Summer squash).

(ii) **Recessive Epistasis (9 : 3 : 4 Ratio).** In this condition, the epistatic gene is recessive to its own allele. Thus the epistatic gene can have its inhibiting influence only when it is in homozygous condition. The F_2 ratio is generally 9 : 3 : 4. **Example :** Coat colour in mice.

Duplicate Genes or Pseudoalleles (15 : 1 Ratio)

They were observed by **G.H. Shull** in Shepherd's purse (*Capsella bursa pastoris*)

Duplicate genes or factors are two or more independent genes present on different chromosomes which determine the same or nearly same phenotype so that either of them can produce the same character. The independent genes do not have cumulative effect. They produce the same phenotype whether present in homozygous or heterozygous state.

Example. Endosperm colour in maize; F_2 ratio : 15 yellow : 1 white.

Polymeric or Additive Genes (9 : 6 : 1 Ratio)

Two independent dominant genes, whether present in homozygous or heterozygous condition, have similar phenotypic effect when present individually but produce a cumulative or double effect when found together. A dihybrid ratio of 9 : 6 : 1 is obtained in the F_2 generation as phenotypes produced by single gene dominance of the two different genes are similar. **Example :** Pericarp colour in wheat; F_2 ratio : 9 deep red : 6 light red : 1 white.

Complementary Genes (9 : 7 Ratio)

They are those nonallelic genes which independently show a similar effect but produce a new trait when present together in the dominant form. Complementary genes were first studied by Bateson and Punnet (1906) in case of flower colour of Sweet Pea (*Lathyrus odoratus*). The latter is also an example of **recessive epistasis** where the recessive homozygous alleles of one type suppresses the effect of dominant alleles of the other type. Here, the flower colour is purple if dominant alleles of two genes are present together (C—P—). The colour is white if the double dominant condition is absent (ccP—, C—pp, ccpp). Bateson and Punnet (1906) crossed two white flowered strains (CCpp, ccPP) of Sweet Pea and obtained purple flowered plants (CcPp) in the F_1 generation. Clearly both the parents have contributed a gene or factor for the synthesis of this purple colour. The purple flowered plants of F_1 generation were then allowed to self-breed. Both purple and white flowered plants appear in the F_2 generation in the ratio of 9 : 7. It is a modification of the dihybrid ratio of 9 : 3 : 3 : 1. The appearance of purple colour in 9/16 population shows that the colour is determined by two dominant genes (C and P). When either of the two is absent (ccPP or CCpp, ccPp or Ccpp), the pigment does not appear.

It is believed that the dominant gene C produces an enzyme which converts the raw material into chromagen. The dominant gene P gives rise to an oxidase enzyme that changes chromagen into purple anthocyanin pigment. This is confirmed by mixing the extract of the two types of flowers when purple colour is formed. Thus purple colour formation is two-step reaction and the two genes cooperate to form the ultimate product.



Supplementary Genes (9 : 3 : 4 Ratio)

Supplementary genes are a pair of nonallelic genes, one of which produces its effect independently in the dominant state while the dominant allele of the second gene (supplementary gene) needs the presence of other gene for its expression.

Supplementary Genes in Lablab. Lablab has two genes, K and L. In the recessive state the second or supplementary gene (ll) has no effect on seed coat colour. Dominant K independently produces Khaki colour while its recessive allele gives rise to buff colour irrespective of the supplementary gene being dominant or recessive. In the dominant state the supplementary gene (L—) changes the effect of dominant allele of pigment forming gene (K) into chocolate colour. F_2 ratio is 9 : 3 : 4.

Collaborative Genes (9 : 3 : 3 : 1 Ratio)

They are two nonallelic genes which not only are able to produce their own effects independently when present in the dominant state but can also interact to form a new trait. Comb types in poultry is an example of collaborative supplementary genes, P and R. When none of these genes is present in the dominant state (pprr), **single comb** is formed. In case P alone is dominant, a **pea comb** is formed (Pprr, PPrr). If R alone is dominant, a **rose comb** is obtained (ppRr, ppRR). A **walnut comb** is formed when both P and R occur together in dominant state (P — R —) to produce supplementary effect.

When pure pea combed and pure rose combed birds are crossed, all the offspring of F_1 individuals have walnut comb. On inbreeding the walnut combed birds, the F_2 generation comes to have all the four types of combs in the ratio of 9 walnut : 3 pea : 3 rose : 1 single.

Differences between Complementary and Supplementary Genes

Complementary Genes	Supplementary Genes
<ol style="list-style-type: none"> 1. They are a pair of nonallelic genes, both of which independently express similar phenotypic trait. 2. Both the genes interact to produce a completely new trait. 3. The F_2 ratio is generally 9 : 7. 	<ol style="list-style-type: none"> 1. They are a pair of nonallelic genes where only one is able to express its effect independently. 2. The supplementary gene modifies the expression of the independently expressing gene. 3. The F_2 ratio is generally 9 : 3 : 4.

S. No.	Types of non-allelic gene interactions	Dihybrid phenotypic ratios in F_2 generation
1.	Dominant Epistasis	12 : 3 : 1
2.	Recessive Epistasis	9 : 3 : 4
3.	Duplicate Genes	15 : 1
4.	Polymeric or Additive Genes	9 : 6 : 1
5.	Complementary Genes	9 : 7
6.	Supplementary Genes	9 : 3 : 4
7.	Collaborative Genes	9 : 3 : 3 : 1
8.	Inhibitory Genes	13 : 3

PLEIOTROPY (PLEIOTROPIC GENES)

A condition in which a single gene influences more than one trait is known as **pleiotropy** (Gr. *pleion* – more, *tropos* – turn) and such a gene is called **pleiotropic gene**.

Explanation. Pleiotropy is due to effect of the gene on two or more inter-related metabolic pathways that contribute to formation of different phenotypes. It is not essential that all the traits are equally influenced. Sometimes the effect of a pleiotropic gene is more evident in case of one trait (**major effect**) and less evident in case of others (**secondary effect**). Occasionally a number of related changes are caused by a gene. They are together called **syndrome**.

Examples (i). In cotton a gene for the lint also influences the height of plant, size of the boll, number of ovules and viability of seeds.

(ii) In Garden Pea the gene which controls the flower colour also controls the colour of the seed coat and presence of red spots in the leaf axils.

(iii) In *Drosophila* white eye mutation causes depigmentation in many parts of the body.

(iv) In transgenic organisms, the introduced gene often produces different effects depending upon place of introgression.

(v) In human beings pleiotropy is exhibited by **syndromes** called **sickle cell anaemia** and **phenylketonuria**.

(a) In **sickle cell anaemia**, the genes which cause this disease alter the type of haemoglobin and also change the form of RBCs.

(b) **Phenylketonuria (PKU; Folling, 1934)** is an inborn, autosomal, recessive metabolic disorder in which the homozygous recessive individual lacks the enzyme **phenylalanine hydroxylase** needed to change phenylalanine (amino acid) to tyrosine (amino acid) in liver. It results in **hyperphenylalaninemia** which is characterised by accumulation and excretion of phenylalanine, phenylpyruvic acid and related compounds. Lack of the enzyme is due to the **abnormal** autosomal recessive gene on **chromosome 12**. This defective gene is due to substitution. Affected babies are normal at birth but within a few weeks there is rise (30 – 50 times) in plasma phenylalanine level which impairs brain development. Usually by six months of life severe mental retardation becomes evident. If these children are not treated about one third of these children are unable to walk and two-thirds cannot talk. Other symptoms are mental retardation, decreased pigmentation of hair and skin and eczema. Although large amounts of phenylalanine and its metabolites are excreted in the urine and sweat, yet there is accumulation of phenylalanine and phenyl pyruvate in brain that results in its damage. The heterozygous individuals are normal but carriers. It occurs in about 1 in 18000 births among white europeans. It is very rare in other races. Blood and urine tests of neonates can indicate the disease.

POLYGENIC INHERITANCE

Inheritance is of two types — qualitative and quantitative.

Qualitative Inheritance (Monogenic Inheritance). It is the type of inheritance in which a single dominant gene influences a complete trait. Presence of two such dominant genes does not alter the phenotype. The genes in which dominant allele expresses the complete trait are called **monogenes**, e.g., TT or Tt for tallness in Pea. Qualitative inher-

itance produces a sort of *discontinuous trait variations** in the progeny, e.g., either tallness or dwarfness. Intermediate forms or continuous trait variations* are not produced.

Quantitative Inheritance (Polygenic Inheritance). It is a type of inheritance controlled by generally three or more genes in which the dominant alleles have cumulative effect with each dominant allele expressing a part or unit of the trait, the full trait being shown only when all the dominant alleles are present. The genes involved in quantitative inheritance are called polygenes. Quantitative inheritance is, therefore, also called **polygenic inheritance**. It is also named as **multiple factor inheritance**. A few instances of quantitative inheritance are kernel colour in wheat, cob length in Maize, skin colour in human beings, human intelligence, milk and meat yield in animals, height in human beings and several plants, yield of crop plants including size, shape and number of seeds or fruits per plant.

A **polygene** is defined as a gene where one dominant allele controls only a unit or partial quantitative expression of a trait. It is also termed as a gene in which a dominant allele individually produces a slight effect on the phenotype but in the presence of similar other dominant allele controls the quantitative expression of a trait due to cumulative effect. Hence, polygenes are also called **cumulative genes**.

The traits controlled by quantitative inheritance are sometimes known as **metric traits** because they can be measured in terms of unit of size, height, weight or number. Quantitative inheritance is further characterised by the occurrence of intermediate forms ('continuous variations') between the parental types. Here a cross between two pure breeding parents does not produce dominant trait of one parent but instead an intermediate trait is exhibited. Similarly in F_2 generation apart from the two parental types there are several intermediate types which link the two parental traits. Because of the latter, quantitative inheritance is also called **blending inheritance**. The dominant polygenic alleles which contribute to the expression of the trait are called **contributing alleles** while the recessive polygenic alleles are known as **non-contributing alleles**.

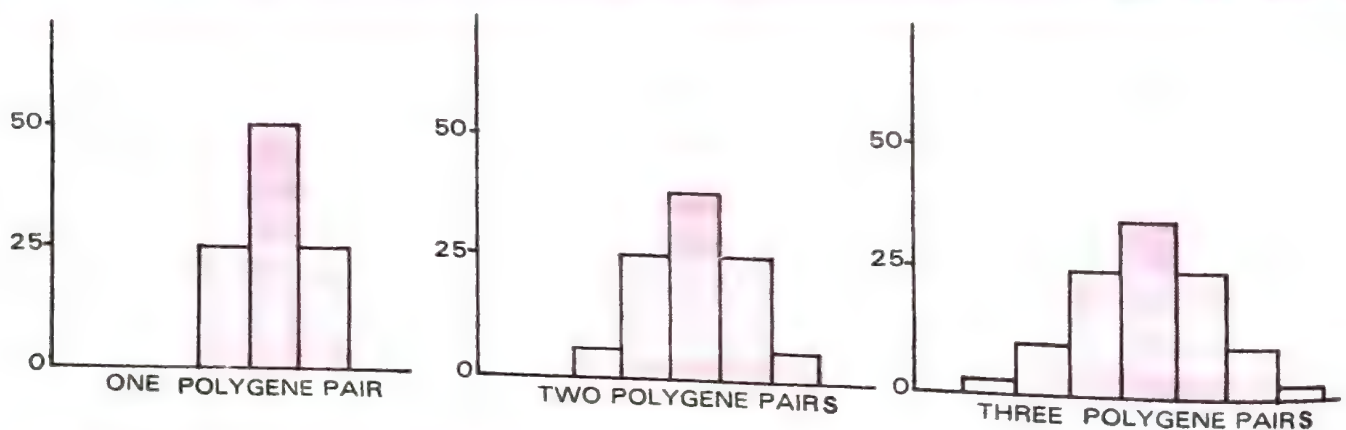


Fig. 5.26. Histograms showing the distribution of F_2 phenotypes in case of polygenic inheritance.

Quantitative or polygenic inheritance was first studied by J. Kolreuter (1760) in case of height in tobacco and F. Galton (1883) in case of height and intelligence in human beings. Nilsson-Ehle (1908) obtained the first experimental proof of polygenic inheritance in case of kernel colour in wheat. Polygenic inheritance occurs in case of plant height, crop yield,

*They should not be confused with continuous and discontinuous variations which are respectively formed due to recombinations and mutations.

milk yield, intelligence height and skin colour in humans. It is easily influenced by environment. Polygenic inheritance can be known from the frequency distribution of phenotypes. In monogenic or qualitative inheritance the phenotypes are two (3 : 1) in case of single gene pair and 4 (9 : 3 : 3 : 1) in case of two pairs of genes. In polygenic or quantitative inheritance the number of phenotypes is 3 (1 : 2 : 1) in case of one polygene pair, 5 (1 : 4 : 6 : 4 : 1) in case of two polygene pairs and 7 (1 : 6 : 15 : 20 : 15 : 6 : 1) when three polygene pairs are involved. Thus we see that the number of intermediate types increases with the increase in the number of polygenes but the number of parental types remain the same (2 in the above cases). The possible origin of polygenes is (i) Duplication of chromosome part (ii) Polyploidy or increase in chromosomes number (iii) Mutations producing genes having similar effect.

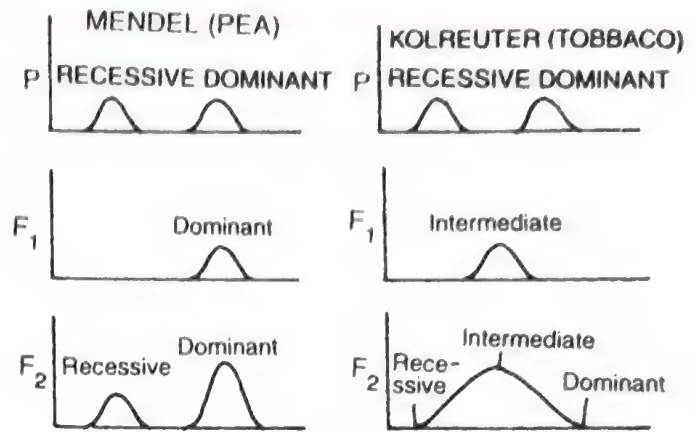


Fig. 5.27. Difference between monogenic (qualitative) and polygenic (quantitative) inheritance as respectively found in Pea by Mendel and Tobacco by Kolreuter.

Differences between Monogenes and Polygenes (Fig. 5.26-27)

<i>Monogenes/Monogenic Inheritance</i>	<i>Polygenes/Polygenic Inheritance</i>
<ol style="list-style-type: none"> 1. They produce discontinuous variations in the expression of traits. 2. A single dominant allele expresses the complete trait. 3. Monogenic inheritance controls qualitative traits. 4. A character is represented in an individual by a pair of alleles. 5. F_1 individuals are similar to dominant parent. 6. F_2 individuals resemble both the parents in the ratio of 3 : 1. 7. No intermediates are produced in monogenic or qualitative inheritance. 8. There is no cumulative action in the presence of two dominant genes. 9. Individuals with dominant phenotype are more numerous than with recessive phenotype. 10. Environment has lesser effect on phenotypic expression. 	<ol style="list-style-type: none"> 1. Polygenes produce continuous variations in the expression of traits. 2. A single dominant allele expresses only a unit of the trait. 3. Polygenic inheritance controls quantitative or metric trait. 4. A character is represented by three to several pairs of alleles. 5. F_1 individuals are intermediate between the two parents. 6. Depending upon the number of polygenes, $2/4$ (one pair), $2/16$ (two pairs) or $2/64$ (three pairs) F_2 individuals resemble the parental types. 7. Intermediates are quite common in polygenic or quantitative inheritance. 8. The dominant genes have cumulative effect on the expression of the trait. 9. Individuals with dominant trait are usually as few as with recessive trait. Intermediate forms are more numerous. 10. Environment has greater effect on phenotypic expression.

Two important examples of polygenic inheritance are kernel colour in wheat and human skin colour.

1. **Kernel Colour in Wheat.** As stated earlier Nilsson-Ehl (1908) first investigated the inheritance of kernel colour in wheat. He found that the kernel colour in wheat is determined by three pairs of genes.

2. **Human Skin Colour.** It was first studied by Davenport (1913) in case of Negro-caucasian intermarriages in Jamaica and Muda (Malayasia). Human skin colour is caused by pigment called **melanin**. The quantity of melanin is due to three pairs of polygenes (A, B and C). If black or very dark (AABBCC) and white or very light (aabbcc) individuals marry, the offspring or individuals of F_1 generation show intermediate colour often called **mulatto** (AaBbCc). When two such individuals of intermediate colour marry, the skin colour of the

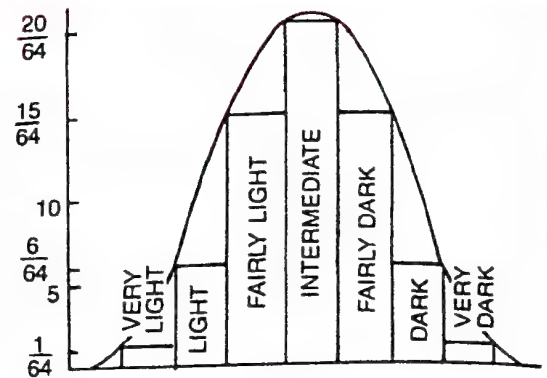


Fig. 5.28. Histogram and bell shaped curve produced from the frequency of various skin phenotypes produced in F_2 generation after a cross between black and white individuals.

White aabbcc (very light)		Black AABBCC (very dark)		Parents					
abc		ABC		Gametes					
AaBbCc Intermediate				F ₁ generation					
Gametes →	ABC	aBC	AbC	ABc	abC	Abc	aBc	abc	
↓	ABC	AABBCC very dark	AaBBCC dark	AABbCC dark	AABBCC dark	AaBbCC fairly dark	AABbCc fairly dark	AaBBCC fairly dark	AaBbCc intermediate
	aBC	AaBBCC dark	aaBBCC fairly dark	AaBbCC fairly dark	AaBBCC fairly dark	aaBbCC intermediate	AaBbCc intermediate	aaBBCC intermediate	aaBbCc fairly light
	AbC	AABbCC dark	AaBbCC fairly dark	AABbCC fairly dark	AABbCC fairly dark	AabbCC intermediate	AABbCc intermediate	AaBbCc intermediate	AabbCc fairly light
	ABc	AABbCc dark	AaBBCC fairly dark	AABbCc fairly dark	AABbCc fairly dark	AaBbCc intermediate	AABbCc intermediate	AaBBcc intermediate	AaBbcc fairly light
	abC	AaBbCC fairly dark	aaBbCC intermediate	AabbCC intermediate	AaBbCc intermediate	aabbCC fairly light	AabbCc fairly light	aaBbCc fairly light	aabbCc light
	Abc	AABbCc fairly dark	AaBbCc intermediate	AabbCc intermediate	AABbCc intermediate	AabbCc fairly light	AABbCc fairly light	AaBbcc fairly light	Aabbcc light
	aBc	AaBBCC fairly dark	aaBBCC intermediate	AaBbCc intermediate	AaBBcc intermediate	aaBbCc fairly light	AaBbcc fairly light	aaBBcc fairly light	aaBbcc light
	abc	AaBbCc intermediate	aaBbCc fairly light	AabbCc fairly light	AaBbcc fairly light	aabbCc light	Aabbcc light	aaBbcc light	aabbcc very light

Phenotypes : Very Dark (Black)—1, Dark—6, Fairly Dark—15, Intermediate—20, Fairly Light—15, Light—6, Very Light (White)—1.

Fig. 5.29. Quantitative inheritance of Skin Colour in human beings.

children will vary from very dark or black to very light or white. A total of eight allele combinations is possible in the gametes forming 27 distinct genotypes distributed into 7 phenotypes (Fig. 5.29) — 1 very dark, 6 dark, 15 fairly dark, 20 intermediate, 15 fairly light, 6 light and 1 very light.

A histogram prepared from the frequencies of various phenotypes shows a bell shape curve (Fig. 5.28).

Chromosomal Theory of Inheritance

Chromosomal theory of inheritance was proposed by **Sutton** and **Boveri** independently in 1902. In 1933 **T. H. Morgan** confirmed the findings of Sutton and Boveri. He was the first to associate a specific gene with a specific chromosome. The chromosomal theory of inheritance states that genes (Mendelian factors) are located at specific loci on the chromosomes and it is the chromosomes which segregate (separate) and assort (distribute into groups of same kind) independently during meiosis and recombine at the time of fertilization in the zygote. With the emergence of this theory, the cytology and genetics converged as **cytogenetics**.

The salient features of chromosomal theory of inheritance.

1. Gametes (*i.e.*, sperms and ova) constitute bridge between one generation and the next generation. The sperms and ova must carry all hereditary traits.
2. Both the sperm and egg contribute equally in the heredity of the offspring. The sperm provides only nuclear part to the zygote. As such hereditary characters must be carried by nuclear materials. There is fusion of the sperm and egg nuclei during fertilization.
3. Nucleus contains chromosomes. Therefore, chromosomes must carry the hereditary traits.
4. Every chromosome or chromosome pair has a definite role in the development of an individual. Loss of a complete or part of the chromosome produces structural and functional deficiency in the organism.
5. Like the hereditary traits the chromosomes retain their number, structure and individuality throughout the life of an organism and from generation to generation. The two neither get lost nor mixed up. They behave as units.
6. Both chromosomes as well as genes occur in pairs in the somatic or diploid cells.
7. A gamete contains only one chromosome of a type and only one of the two alleles of a character.
8. The paired condition of both chromosomes as well as genes is restored during fertilization.
9. Genetic homogeneity and heterogeneity, dominance and recessiveness can be suggested by chromosomal type and behaviour.
10. Homologous chromosomes synapse during meiosis and then segregate (separate) independently into different cells which establishes the quantitative basis for segregation and independent assortment of hereditary factors.
11. In many organisms, sex of an individual is determined by specific chromosomes called **sex chromosomes**.

Parallelism (Similarity) Between Genes (Mendelian Factors) and Chromosomes

- (i) Both genes (Mendelian factors) and chromosomes are transferred from generation to generation without any change.

(ii) In diploid cells, chromosomes occur in homologous pairs. Genes also occur in allelic pairs. One member of a pair is obtained from maternal parent and the other from the paternal parent.

(iii) Prior to cell division both chromosome and an allele of a gene get replicated. During mitosis the replicated chromosome and the replicated allele split which pass into the two daughter cells. The process of replication and distribution maintains similarity in the genetic composition of the cells of a multicellular organism.

(iv) Both segregate (separate) during gamete formation (meiosis) so that a gamete receives only one chromosome and one allele of each pair.

(v) Fusion of two haploid gametes restores the diploid chromosome number and allelic pairs in the offspring.

(vi) Both chromosomes and alleles (Mendelian factors) follow **law of segregation**.

(vii) Both genes and chromosomes show **law of independent assortment** (numbers of each pair separate and come together independently of other pairs). But it is important to note that only those gene pairs show independent assortment which occur on different chromosomes.

Chromosomal Explanation of Law of Segregation

Figure 5.30. explains Mendel's law of segregation of Mendelian factors (genes) in terms of movement of chromosomes during meiosis.

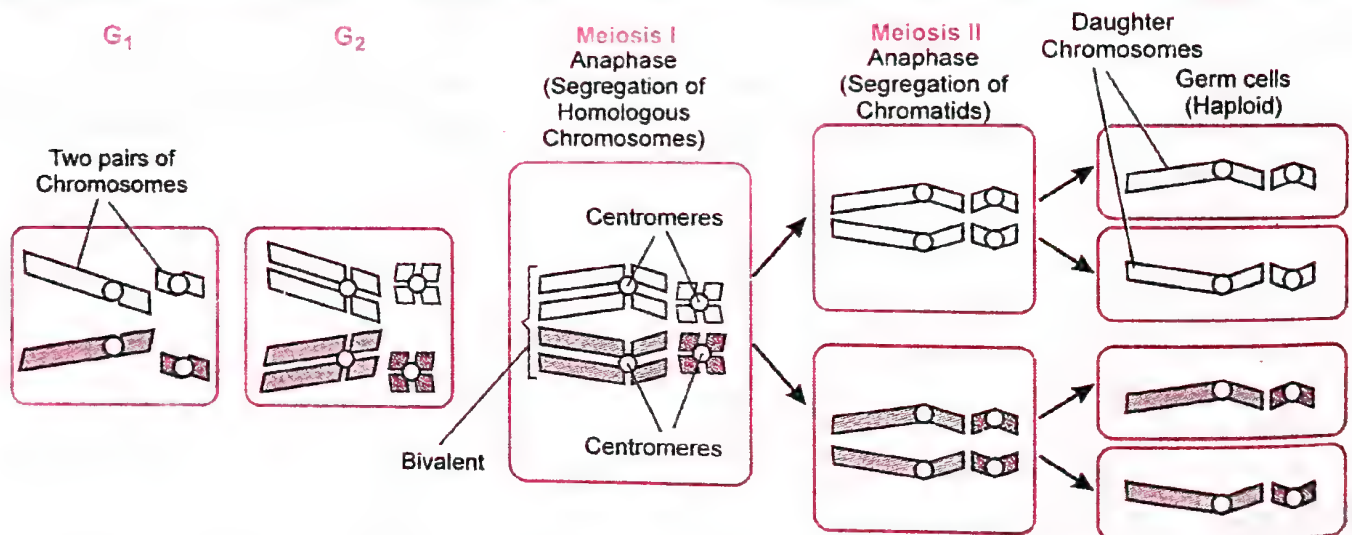


Fig. 5.30. Formation of four germ cells from one cell (with four chromosomes) by meiosis to show segregation of homologous chromosomes.

At the time of gamete formation, homologous chromosomes bearing the factors (genes) pair segregate (separate) in anaphase-1 of meiosis 1 producing two daughter cells. In anaphase II of meiosis II, the two chromatids of each chromosome separate and enter the two new daughter cells. These four daughter cells, thus formed have one chromosome along with one allele of a gene or factor present in it. Thus the daughter cells are haploid and known as gametes.

Chromosomal Explanation of Law of Independent Assortment

Figure 5.31 explains Mendel's law of independent assortment of Mendelian factors (genes) in terms of movement of chromosomes during meiosis. There are present two pairs of genes on two different pairs of chromosomes.

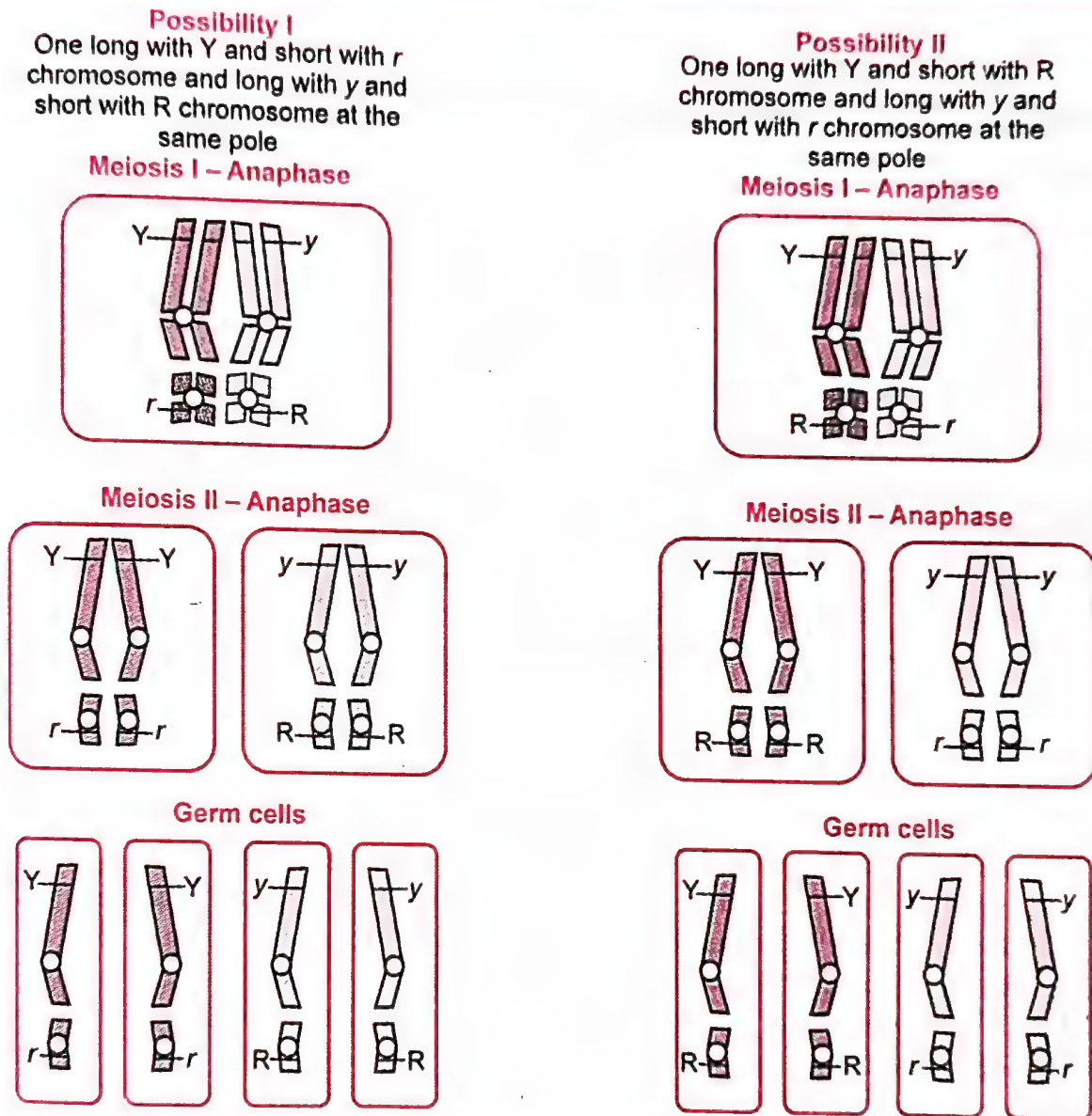


Fig. 5.31. Independent assortment of chromosomes during meiosis. During Anaphase 1 of meiosis 1, the two chromosome pairs, that were aligned at metaphase plate, separate out randomly.

- (i) Allelic genes of seed colour (yellow and green) are present on one homologous pair.
- (ii) Allelic genes of seed shape (round and wrinkled) are present on another homologous chromosome pair.
- (iii) Parents homozygous for yellow and round seeds produce gametes which have one chromosome of each type and therefore, they have one gene for yellow colour (Y) and one gene for round shape (R).

Similarly, parents homozygous for green colour (*y*) and wrinkled shape (*r*) seeds

produce gametes which have one chromosome of each type, one having *r* gene and other having *y* gene.

(iv) Cross-pollination between these two types of parents results in the formation of F_1 heterozygotes having genotype $YyRr$.

(v) The F_1 heterozygous parents produce four types of gametes having YR , yR , Yr and yr genes.

(vi) These gametes randomly fuse and give rise to F_2 generation with four types of pea plants in dihybrid ratio of 9 : 3 : 3 : 1.

***Drosophila* as Experimental Material for Genetic Studies**

Thomas Hunt Morgan (the father of experimental genetics) selected fruitfly *Drosophila melanogaster* (the Jackpot of Genetics) as experimental materials though it is small sized (2mm size) because of following advantages in *Drosophila* over Pea. (i) It is easily available hovering over ripe Mango/Banana fruits where it feeds over yeast cells present over the fruit surface. (ii) The flies can be reared inside bottles having yeast culture over medium containing cream of wheat, molasses and agar. (iii) A new generation can be raised within 2 weeks with single mating producing hundreds of individuals. (iv) The animals can be temporarily inactivated with ether and examined by hand lens/dissection microscope. (v) Female is distinguishable from male by its larger size and ovipositor at the rear end. (vi) The animals possess four pairs of chromosomes of different sizes. The male fly possesses XY sex chromosomes while the female has XX chromosomes. Y chromosome is hooked and easily distinguished. (vii) Polytene chromosomes occur in salivary glands of larva which can indicate any type of abnormality. (viii) Breeding *Drosophila* is quite cheap. Further, it can be done throughout the year.

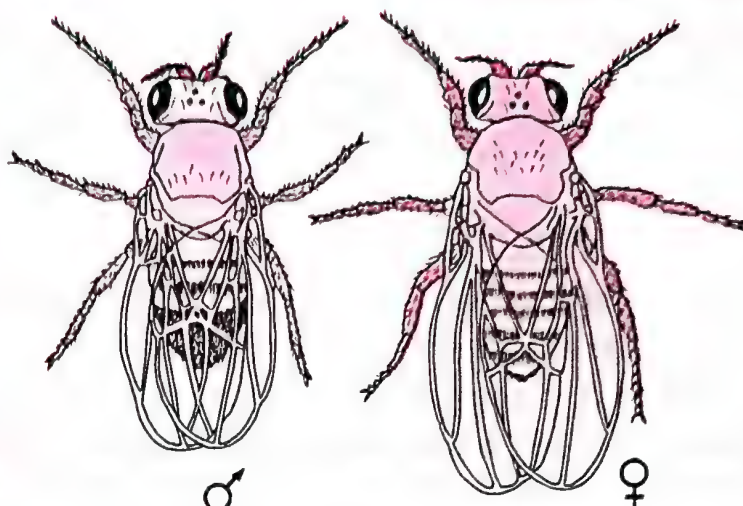
Contribution of Morgan in Genetics

Thomas Hunt Morgan (1866–1945), an American genetist and Nobel Prize winner of 1933, is considered as **Father of Experimental Genetics** for his work on and discovery of linkage, crossing over, sex linkage, criss cross inheritance, linkage maps, mutability of genes, etc. He is called **fly man of genetics** because of selecting fruit fly (*Drosophila melanogaster*) as research material in experimental genetics. It was largely due to his book, "**The Theory of Gene**", that genetics was accepted as a distinct branch of biology. (1) He discovered the basis for variations due to sexual reproduction. (2) He (1910) discovered linkage and distinguished linked and unlinked genes. (3) Morgan and Castle (1911) proposed **Chromosome Theory of Linkage** showing that genes are located in the chromosomes and arranged in linear order. The strength of linkage between genes increases with the decrease in the distance between genes. (4) He proposed **chiasma type hypothesis** showing that chiasmata cause crossing over. (5) Morgan and Sturtevant (1911) found that frequency of crossing over (recombination) between two linked genes is directly proportional to the distance between the two. 1% recombination is considered to be equal to **1 centi Morgan (cM)** or 1 map unit. (6) He worked on sex linked inheritance. Morgan reported a white eyed male *Drosophila* in a population of red eyed flies and proved that gene of eye colour is located on X-chromosome. The male passed its genes on X-chromosome to the daughter while the son gets genes on X-chromosome from the female (mother). It is called **criss-cross inheritance**. (7) He gave **gene theory of inheritance** and suggested that specific gene is associated with a specific chromosome. (8) He produced the students like Sturtevant, Bridges and Muller.



T. H. Morgan

A



B

Fig. 5.32. A, T. H. Morgan (1866–1945). B, *Drosophila melanogaster*.

LINKAGE (Exception to Independent Assortment)

Meaning of Linkage

*Linkage is the tendency of genes to stay together during inheritance through generations without any change or separation due to their being present on the same chromosome. The genes located in the same chromosome are called **linked genes** and those present in different chromosomes are termed **unlinked genes**.*

Demonstration of Linkage

(i) **Linked Genes.** These genes occur on the same chromosome and do not show independent assortment but remain together and are inherited *en block* due to their being present on the same chromosome. They show a dihybrid ratio of 3 : 1 (like monohybrid ratio) and a test cross ratio of 1 : 1 (like monohybrid test cross). Progeny consists of only parental types. Recombinants are absent.

(ii) **Unlinked Genes.** These genes occur on different chromosomes and show independent assortment. Dihybrid ratio is 9 : 3 : 3 : 1 while the dihybrid test cross ratio is 1 : 1 : 1 : 1. In both the crosses, 50% are parental types while 50% are recombinants.

Differences between Linked Genes and Unlinked Genes

Linked Genes	Unlinked Genes
<ol style="list-style-type: none"> 1. These genes are placed on the same chromosome and do not show independent assortment at the time of gamete formation. 2. They show dihybrid ratio of 3 : 1. 3. In dihybrid, they show test cross ratio of 1 : 1. 	<ol style="list-style-type: none"> 1. These genes are located on different chromosomes and undergo independent assortment (segregation). 2. They show dihybrid ratio of 9 : 3 : 3 : 1. 3. In dihybrid, they show a test cross ratio of 1 : 1 : 1 : 1.

Discovery of Linkage

Linkage was first discovered by Bateson and Punnet in 1906 in sweet pea (*Lathyrus odoratus*). However, it was Morgan (1910) who clearly proved and defined linkage on the basis of his breeding experiments in fruitfly *Drosophila melanogaster*. The term linkage was coined by Morgan.

Chromosome Theory of Linkage

In 1911, Morgan and Castle proposed **chromosome theory of linkage**. It states that

- (i) Linked genes occur in the same chromosome.
- (ii) They lie in a linear sequence in the chromosome.
- (iii) There is a tendency to maintain the parental combination of genes except for occasional crossovers.
- (iv) Strength of the linkage between two genes is inversely proportional to the distance between the two, *i.e.*, two linked genes show higher frequency of crossing over if the distance between them is higher and lower frequency if the distance is small.

Linkage Groups

Genes that are present on the same chromosome make one linkage group. They inherit together except for crossing over. It corresponds to a chromosome which bears a linear sequence of genes linked and inherited together. Because the two homologous chromosomes possess either similar or allelic genes on the same loci, they constitute the same linkage group. Therefore, the number of linkage groups present in an individual corresponds to number of chromosomes in its one genome (all the chromosomes if haploid or homologous pairs if diploid). It is known as principle of limitation of linkage groups.

Examples. Fruitfly *Drosophila melanogaster* has four linkage groups (4 pairs of chromosomes), human beings 23 linkage groups (23 pairs of chromosomes), Pea seven linkage groups (7 pairs of chromosomes), *Neurospora* 7 linkage groups (7 chromosomes), *Mucor* 2 linkage groups (2 chromosomes), *Escherichia coli* one linkage group (one prochromosome or nucleoid) while Maize has 10 linkage groups (10 pairs of chromosomes). The size of the linkage group depends upon the size of chromosome. The smaller chromosome will naturally have smaller linkage group while a longer one has longer linkage group. This is subject to the amount of heterochromatin present in the chromosome. Thus Y-chromosome of man possesses 231 genes while human chromosome 1 has 2969 genes.

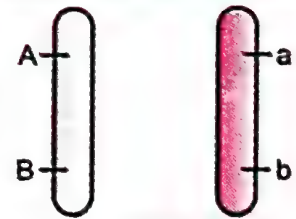
Importance. (i) The number of linkage groups is equivalent to number of chromosomes present in a genome. It proves that genes are present on the chromosomes. (ii) Linkage prevents or reduces the incidence of recombination so that specific varietal or racial characters are retained over the generations. (iii) It is highly useful for maintaining the good characters of the newly developed variety. (iv) Linkage is a biggest headache for breeders because it does not allow them to freely bring all the desirable traits in one variety. (v) It dilutes the use of desirable traits if undesirable ones are also present on the same linkage group, *e.g.*, low ginning and naked seeds or fuzzy seeds and high ginning in American Cotton. (vi) **Marker genes** or genes which express their effect in early growth can indicate the effect of a linked gene which is to express late, *e.g.*, wavy lamina and larger panicle in Millet.

Arrangement of Linked Genes

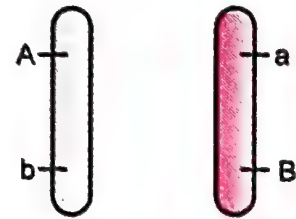
Linked genes in heterozygous organisms can show the following two types of arrangements (Fig. 5.33).

(i) **Cis-Arrangement.** If dominant alleles of both the linked genes are present on one chromosome and their recessive alleles on its homologous chromosome ($AB|ab$). This arrangement is known as **cis-arrangement** (*L. cis* – on this side of) and genes are said to be in **coupling state**.

(ii) **Trans-Arrangement.** If dominant allele of one pair and recessive allele of the second pair are present on one chromosome and recessive and dominant alleles on the other homologous chromosome of a pair (Ab/aB), this arrangement is known as **trans-arrangement** (*L. trans* – on the other side) and genes are said to be in **repulsive state**.



Cis Arrangement of Genes



Trans Arrangement of Genes

Fig. 5.33. Diagram showing *cis* and *trans* arrangements of linked genes.

Types of Linkage

Linkage is of two types : complete and incomplete.

1. **Complete Linkage** (Morgan, 1919). The genes located in the same chromosome do not separate and are inherited together over the generations due to the absence of crossing over. Complete linkage allows the combination of parental traits to be inherited as such.

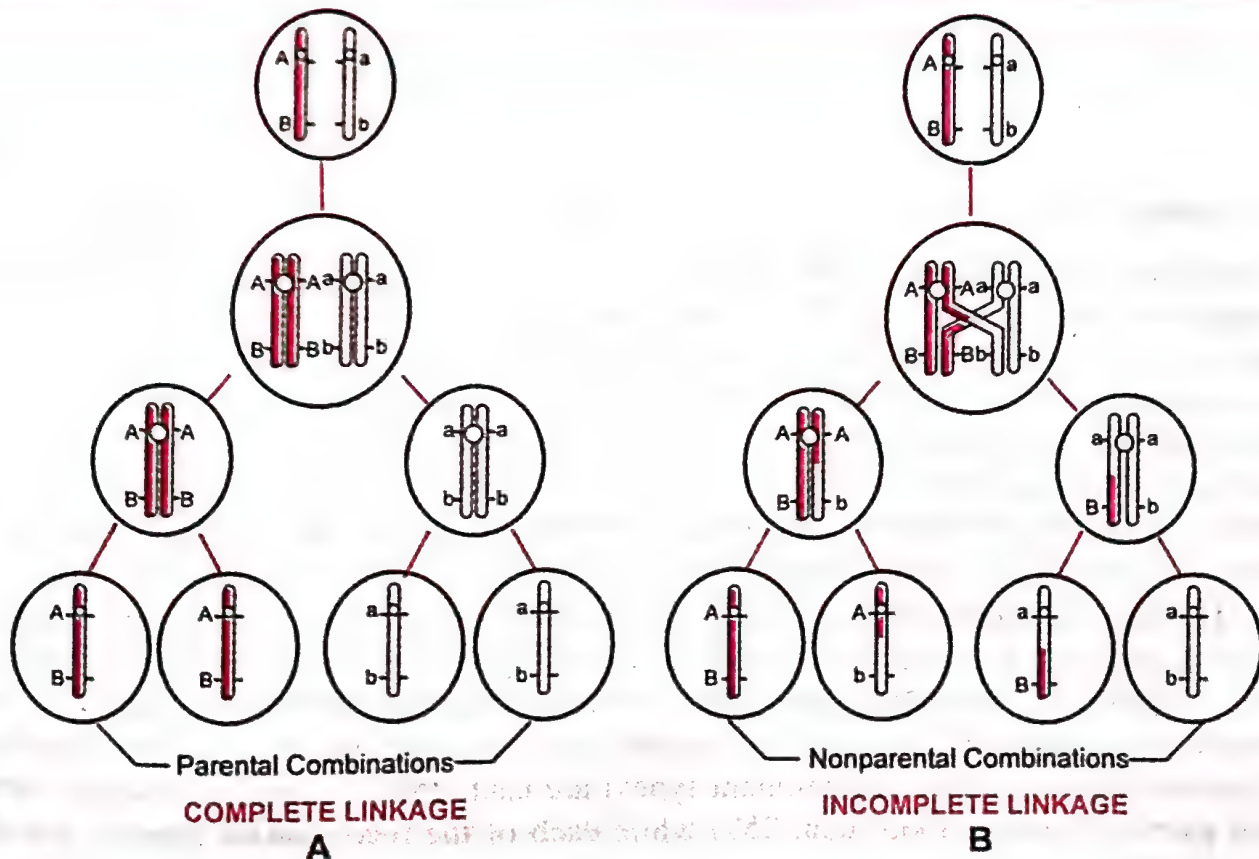


Fig. 5.34. Diagram showing difference between complete and incomplete linkage. Complete linkage — no crossing over and the result is two types of gametes, AB and ab. Incomplete linkage — crossing over takes place during meiosis and the result is four types of gametes AB, Ab, aB and ab

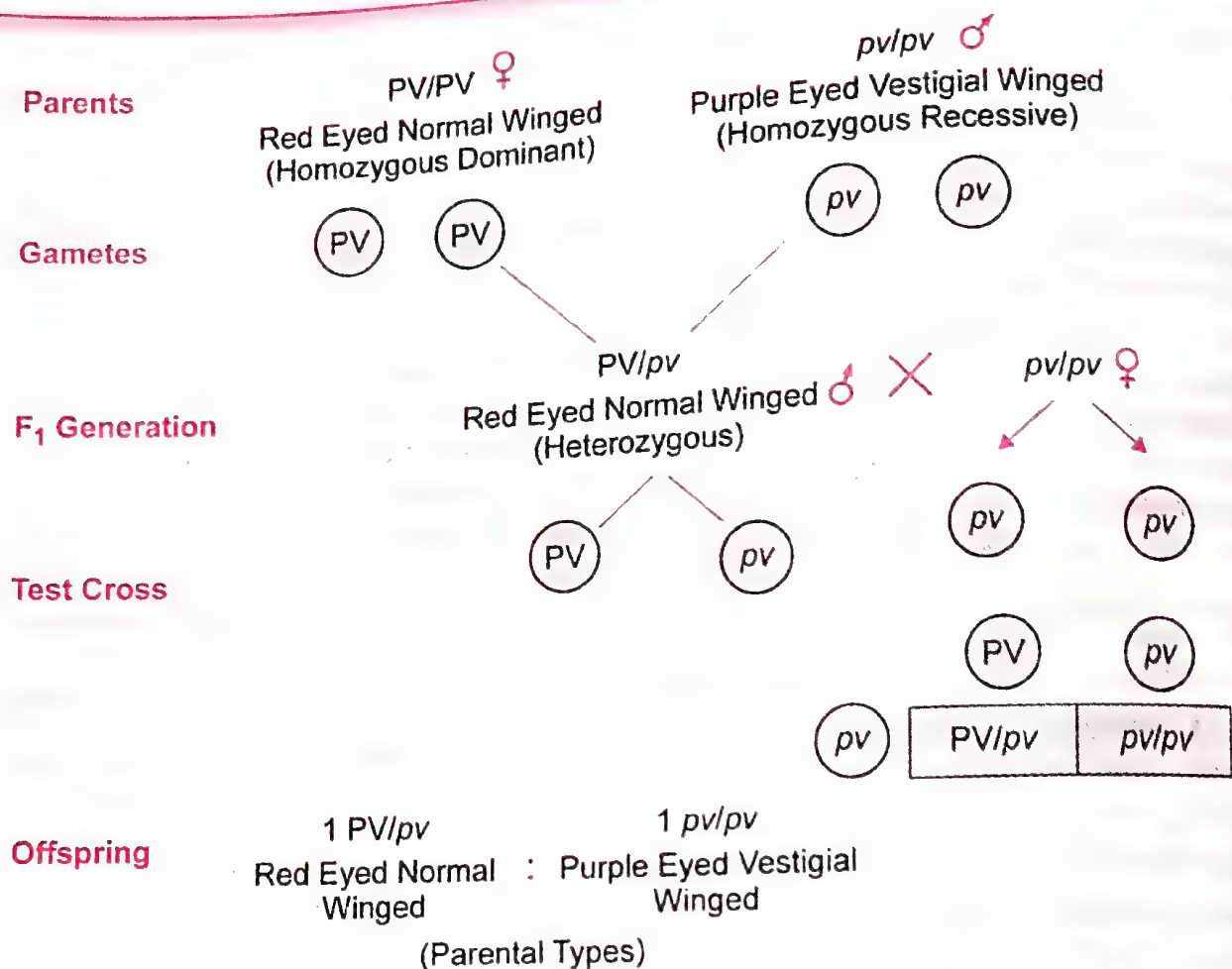


Fig. 5.35. A dihybrid test cross showing complete linkage.

Example. Complete linkage is rare but has been reported in male *Drosophila*.

Complete linkage in male *Drosophila*. A red eyed and normal winged (wild type) homologous female *Drosophila* (PV/PV) is crossed to homozygous recessive purple eyed and vestigial winged male (pv/pv). The progeny or F₁ generation individuals are heterozygous red eyed and normal winged. When F₁ males are test crossed to homozygous recessive female (purple eyed and vestigial winged), only two types of individuals are produced— red eyed normal winged and purple eye vestigial winged in the ratio of 1 : 1 (parental phenotypes only). Similarly during inbreeding of F₁ individuals, recombinant types are absent. There was no crossing over which indicated that the linkage in male *Drosophila* was complete.

2. Incomplete Linkage. Linkage is incomplete when new or non parental combinations of linked genes are also formed. It is due to crossing over and hence produce recombinant progeny besides the parental type. The number of recombinant individuals is usually less than the number expected in independent assortment. In independent assortment all the four types (two parental types and two recombinant types) are each 25%. In case of linkage, each of the two parental types is more than 25% while each of the recombinant types is less than 25%.

Examples. Incomplete linkage is very common and has been studied in various organisms.

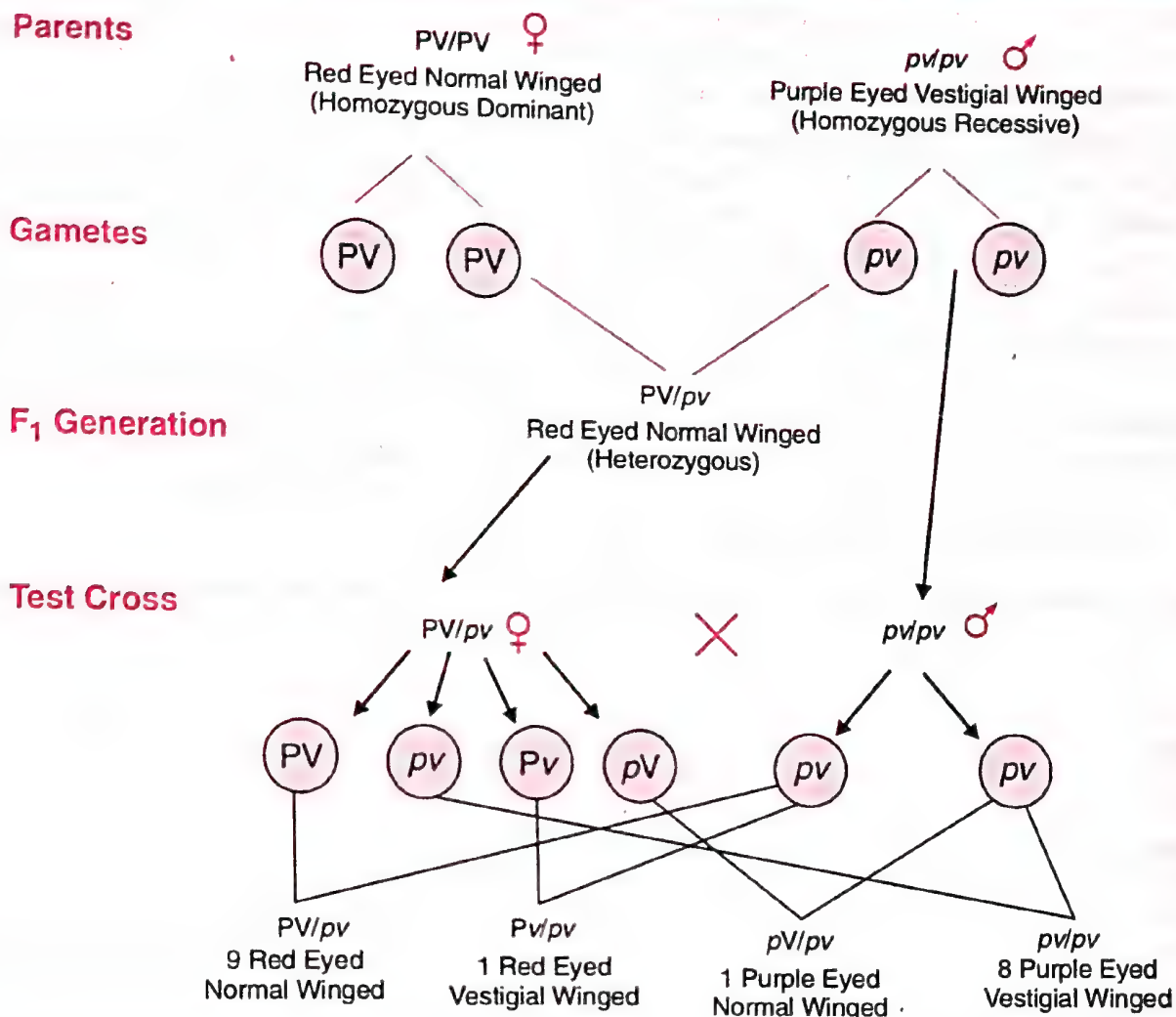


Fig. 5.36. A dihybrid cross showing incomplete linkage.

(i) **Incomplete linkage in female *Drosophila*.** A red eyed normal winged or wild type dominant homozygous female *Drosophila* (PV/PV) is crossed to homozygous recessive purple eyed and vestigial winged male (pv/pv). The progeny or F_1 individuals are heterozygous red eyed and normal winged. F_1 female flies are test crossed with homozygous recessive males. It does not yield the ratio of 1 : 1 : 1 : 1. Instead the ratio comes out to be 9 : 1 : 1 : 8. This shows that the two genes did not segregate independently of each other. The data obtained by Bridges (1916) is as follows:

Phenotype	Progeny	Observed	Expected if Complete Linkage	Expected if Independent Assortment
Parental Types				
(a) Red eyed, normal winged		1339	1420	710
(b) Purple eyed vestigial winged		1195	1420	710
Recombinant Types				
(a) Red eyed, vestigial winged		152	zero	710
(b) Purple eyed, normal winged		152	zero	710

Only 9.3% recombinant types were observed which is quite different from 50% recombinants in case of independent assortment. This shows that in the oocytes of the F_1 generation only some of the chromatids undergo cross-over while the majority is preserved intact. This produces 90.7% parental types in the progeny.

(ii) **Incomplete linkage in Sweet Pea.** In Sweet Pea (*Lathyrus odoratus*) blue flower colour (B) is dominant over red flower colour (b) while the trait of long pollen (L) is dominant over round pollen (l). A Sweet Pea plant heterozygous for both blue flower colour and long pollen (BbLl) was crossed with double recessive red flowered plant with round pollen (bbll). It is similar to test cross. In case the genes of the two traits are unlinked, the progeny should have four phenotypes (Blue Long, Blue Round, Red Long, Red Round) in the ratio of 1 : 1 : 1 : 1 (25% each). In case the two genes are completely linked the progeny should have both the parental types (Blue Long and Red Round) in the ratio of 1 : 1 (50% each). Recombinants should not appear. However, in the above cross Bateson and Punnett (1906) found both parental and recombinant types but with different frequencies in the ratio of 7 : 1 : 1 : 7. (7 + 7 Parental and 1 + 1 recombinant types).

Phenotype	Progeny	Observed frequency	Expected frequency if complete linkage	Expected frequency if Independent assortment
Parental Types	(i) Blue Long	43.7%	50%	25%
	(ii) Red Round	43.7%	50%	25%
Recombinant Types	(a) Blue Round	6.3%	0%	25%
	(b) Red Long	6.3%	0%	25%

Only 12.6% recombinant types were observed against the expected percentage of 50% in case of independent assortment. Therefore, the genes are linked but undergo recombination due to crossing over in some of the cases.

Morgan's concept of Incomplete Linkage. Morgan and his group found that even when genes were grouped on the same chromosome some genes were very tightly linked (showed very low recombination, Fig. 5.37) while others were loosely linked (showed higher recombination Fig. 5.38). Results of two hybrid crosses conducted by Morgan are briefly given below.

(iii) **Incomplete linkage in *Drosophila* for body colour and eye colour.** In *Drosophila*, crossing of yellow bodied (y) and white eyed (w) female with brown bodied (y^+) red eyed (w^+) male produced F_1 to be brown bodied red eyed. On intercrossing of F_1 progeny, Morgan observed that the two genes did not segregate independently of each other and, therefore, the F_2 ratio deviated significantly from expected 9 : 3 : 3 : 1 ratio. He found 98.7% to be parental and only 1.3% recombinants (Fig. 5.37). Thus these genes were very tightly linked and showed very low recombinant.

(iv) **Incomplete linkage in *Drosophila* for eye colour and wing size.** In a second cross in *Drosophila* between white eyed and miniature winged ($wwmm$) female with wild type or red eyed normal winged ($w^+w^+m^+m^+$) males, all the F_1 were found to be of wild type, i.e., red eyed and normal winged. An F_1 female fly was then test crossed with white eyed and miniature winged male. 62.8% of the progeny was of parental types while 37.2% were recombinants (Fig. 5.38). Thus these genes were loosely linked and showed higher recombination.

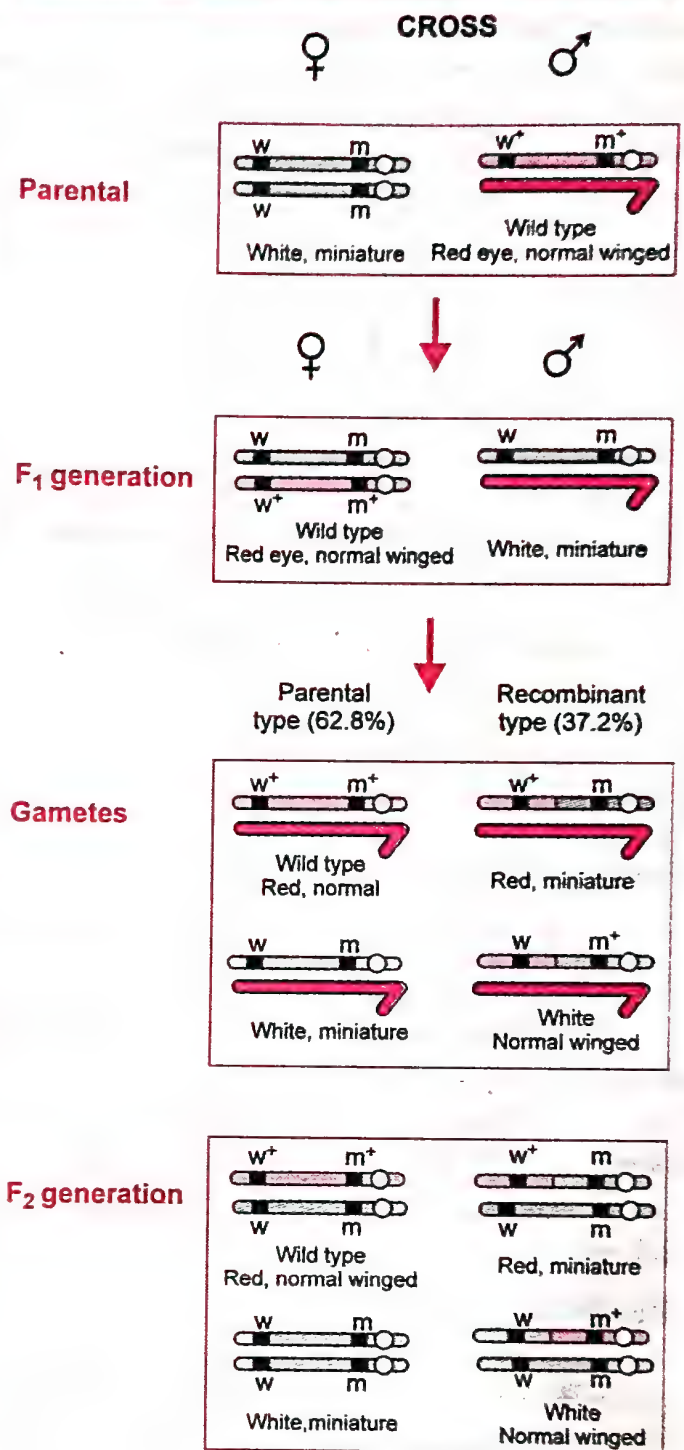
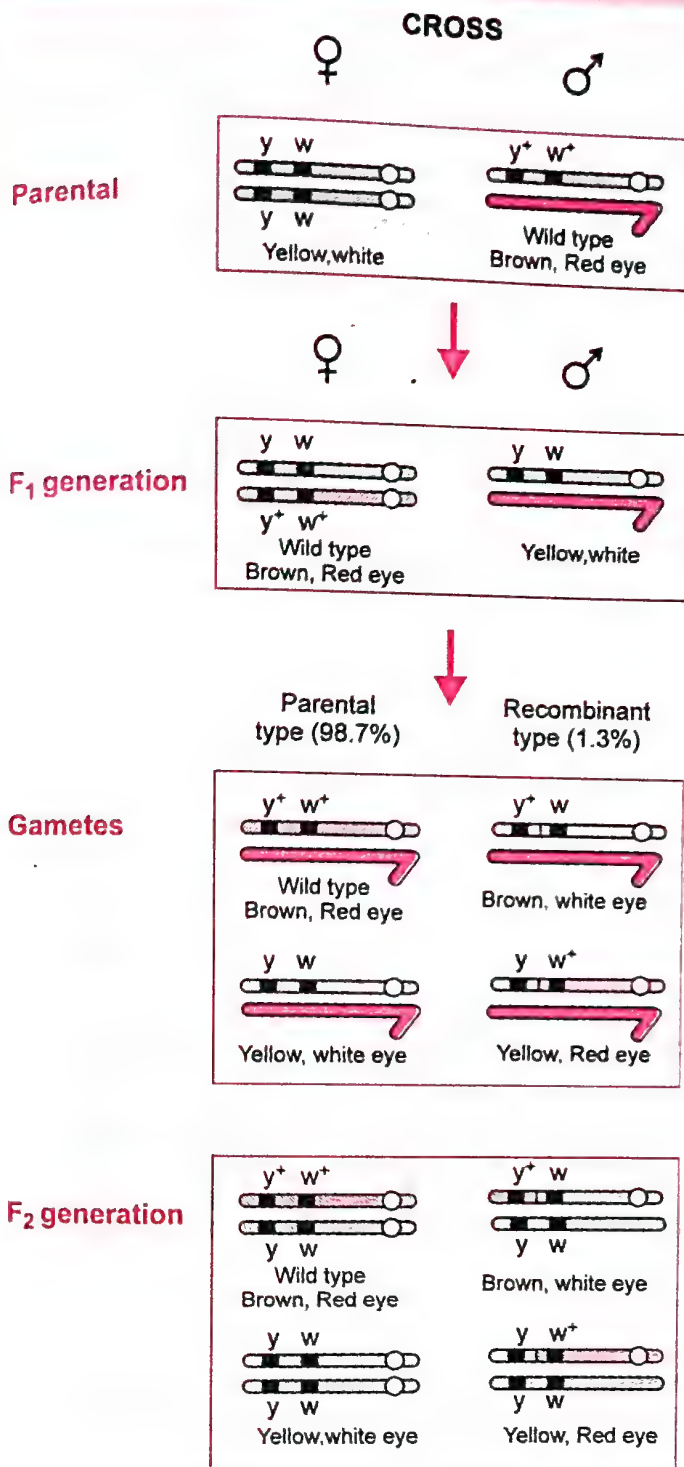


Fig. 5.37. Incomplete linkage in *Drosophila* showing recombination of genes for body colour and eye colour. Results of a dihybrid cross conducted by Morgan, showing cross between gene y and w . Here dominant wild type alleles are represented with (+) sign in superscript.

Fig. 5.38. Incomplete linkage in *Drosophila* showing recombination of genes for eye colour and wing size. Results of a dihybrid cross conducted by Morgan showing cross between gene w and m . Here dominant wild type alleles are represented with (+) sign in superscript.

The strength of linkage between y and w is higher than w and m .

Last two examples (III and IV) of incomplete linkage indicate that linkage between y and w alleles is stronger as compared to linkage between w and m .

Morgan's student **Alfred Sturtevant** used the frequency of recombination between gene pairs on the same chromosome as a measure of the distance between genes and 'mapped' their position on the chromosome. Now-a-days genetic maps are extensively used as a starting point in sequencing of whole genomes as was done in the case of the Human Genome Sequencing Project to be described in the next chapter.

Differences between Complete Linkage and Incomplete Linkage

Complete Linkage	Incomplete Linkage
<ol style="list-style-type: none"> 1. The genes located very closely in the same chromosome remain linked, show complete linkage and are inherited together over the generations without disturbing linkage groups. 2. There is no crossing over between closely linked genes. 3. It is of rare occurrence and reported in organisms like male <i>Drosophila</i>, female silk worm. 4. It produces parental types and no recombinants in the progeny. 	<ol style="list-style-type: none"> 1. The genes are present distantly in the same chromosome and have a tendency to occasionally separate. 2. Crossing over occurs to bring recombinants alongwith parental types. 3. It is quite common. 4. It produces more of parental types (> 50%) alongwith few recombinants (< 50%) in the progeny.

Factors Affecting Linkage

1. **Age.** With advancing age the chances of crossing over are reduced and hence strength of linkage increases.
2. **Temperature.** Rise in temperature increases the chances of crossing over, therefore, decreases the strength of linkage.
3. **Radiation.** The radiation like UV rays and X-rays decreases the linkage. Radiation causes recombination and crossing over.
4. **Distance.** The increase in distance between two genes decreases the percentage of linkage.

Significance of Linkage

1. Linkage reduces the chances of the formation of new combinations of genes in the gametes. Thus it helps to keep the parental racial and important traits together.
2. It helps to maintain the important traits of a newly developed variety.
3. Linkage disallows the plant and animal breeders to combine all valuable traits in a single variety.
4. Linkage groups give important information about the location of genes in the chromosomes.

Linkage Versus Independent Assortment

Both linkage and independent assortment are against each other, therefore, they can be compared.

- (i) When the two pairs of genes (A and B) as shown in the Fig. 5.39 A, located on different pairs of chromosomes, they show independent assortment while entering the gametes during meiosis, forming four types of gametes in equal proportion.

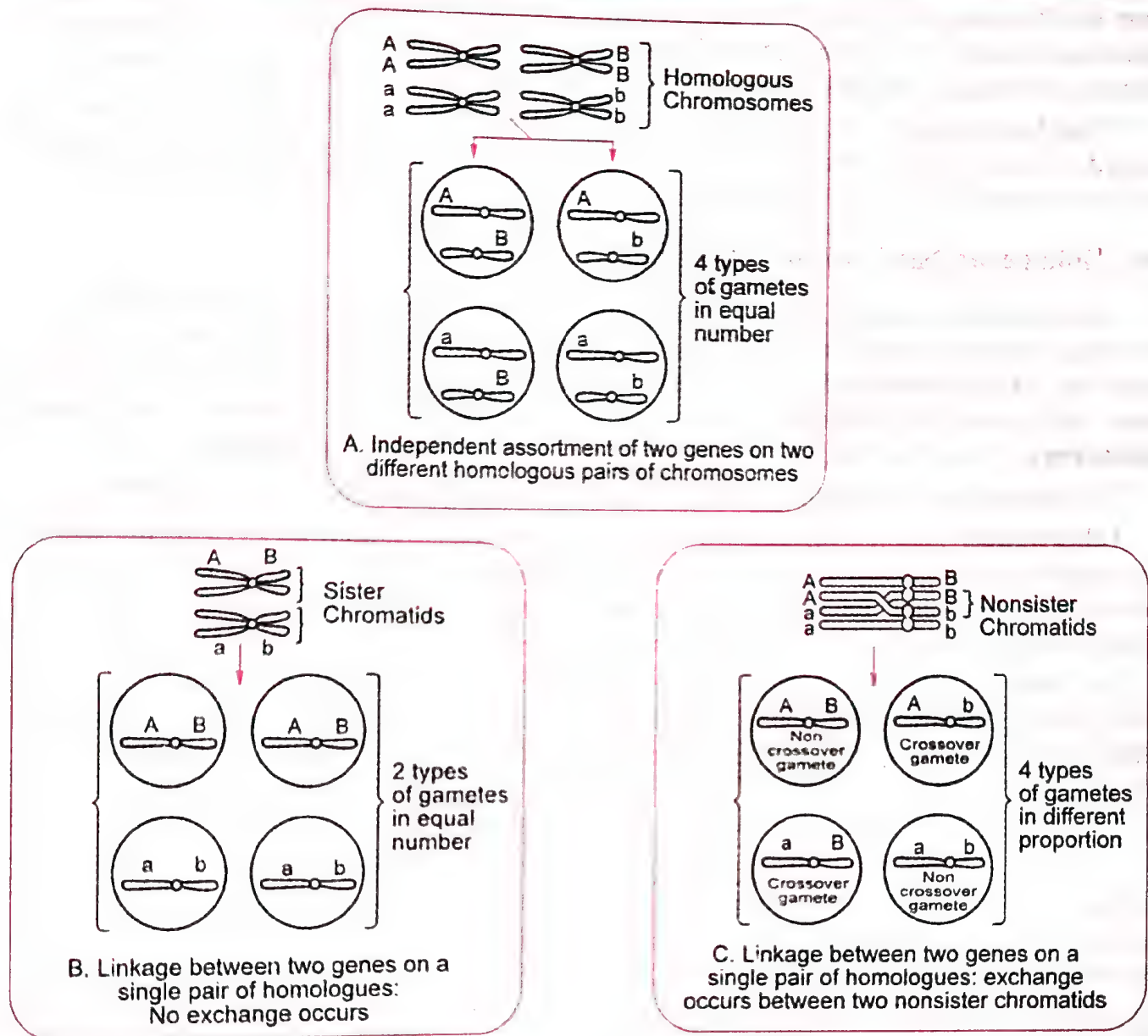


Fig. 5.39. Showing results of independent assortment, linkage and crossing over.

(ii) When the two pairs of genes are present on the same chromosome (*i.e.*, the genes are linked) as shown in the Fig. 5.39 B, at the time of gamete formation during meiosis, the linked genes are unable to separate because there is no crossing over. Thus in the absence of crossing over, only two types of gametes are formed in equal numbers. They carry only parental or non crossover gene combinations. 50% of these gametes possess AB genes and 50% have ab genes.

(iii) When linked genes have undergone crossing over, four types of gametes in different proportion are formed as shown in the Fig. 5.39 C.

Thus linkage is exception to the law of independent assortment.

Why Mendel Missed Linkage ?

Mendel could not note linkage because the seven characters he studied in garden pea, had their genes located on different (non homologous) chromosomes or so far apart on the same chromosome that they got separated by crossing over. Garden pea has seven pairs of

chromosomes. Genes for seed colour and flower colour are located on the same chromosomes but far apart, therefore, they do not behave as linked genes and have 50% chances of separation. Genes for plant height and pod-form show linkage in garden pea. It was only a chance that Mendel had not selected these linked characters for this dihybrid cross.

It has been found by S. Blix that the genes of Mendel's seven selected characters are located on four chromosomes — two genes on chromosome 1, three genes on chromosome 4 and one gene on each of chromosome 5 and 7.

Sex Linkage or Sex-Linked Inheritance

The sex chromosomes (X and Y) carry genes for sex determination and also some genes for some somatic characters. The genes for somatic characters present on sex chromosomes are called **sex-linked genes**. The characters which are controlled by the sex-linked genes are termed **sex linked characters** and their inheritance is known as **sex linked inheritance**. Their location in the sex chromosomes is called **sex linkage**.

Two important sex-linked human diseases are haemophilia and colour blindness.

Inheritance. The sex linkage was first discovered by Morgan in 1910 in the fruitfly, *Drosophila melanogaster*. This has XX sex chromosomes in the female and XY sex chromosomes in the male. Its eye colour is sex linked. The following crosses illustrate the inheritance of X-linked eye colour in *Drosophila*.

(i) **Red-eyed Female × White-eyed Male.** Morgan (1910) noticed a white-eyed male in a culture of red-eyed *Drosophila*. This white-eyed male was mated with a homozygous red-eyed female *Drosophila*. All males and females of F_1 generation were red-eyed.

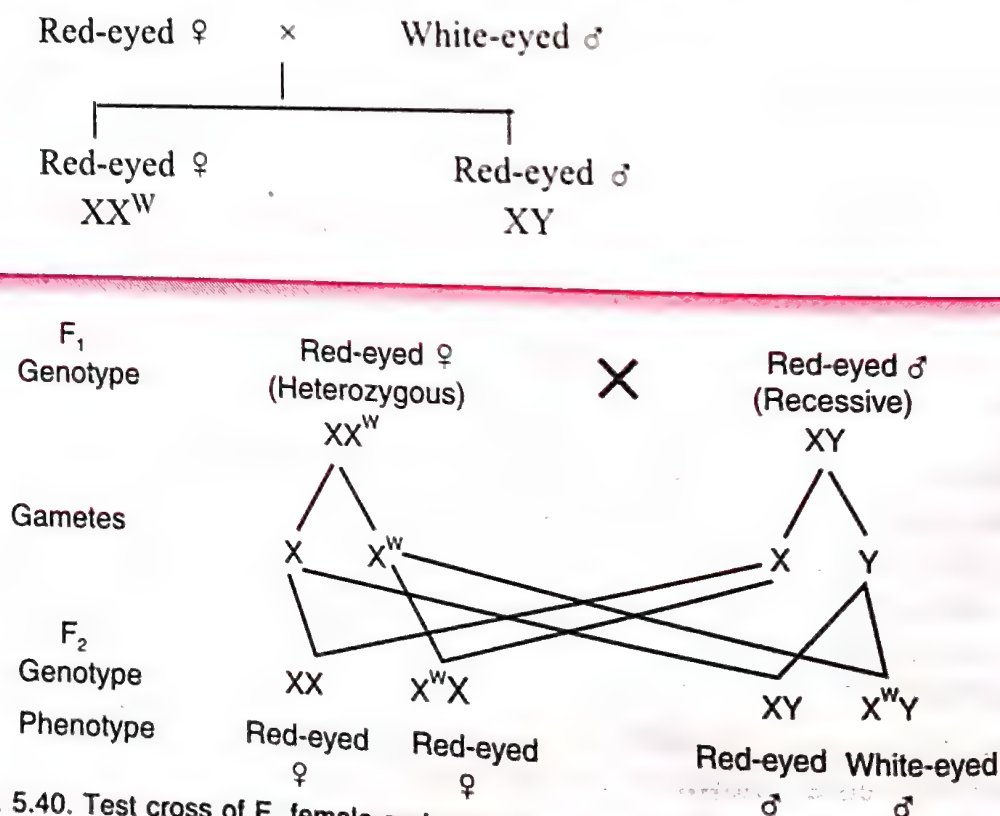


Fig. 5.40. Test cross of F_1 female and recessive male. The F_2 generation has both red and white-eyed males and females in equal proportion.

(ii) **F_1 Red-eyed Female × Red-eyed Male.** When these F_1 females and males were allowed to interbreed by Morgan, the F_2 generation consisted of :

1. Females

All Red-eyed $\left\{ \begin{array}{l} \text{Homozygous (XX)} = 25\% \\ \text{Heterozygous (XX}^W) = 25\% \end{array} \right.$

2. Males

Red-eyed (XY) = $\frac{1}{4} = 25\%$

White-eyed (X^WY) = $\frac{1}{4} = 25\%$

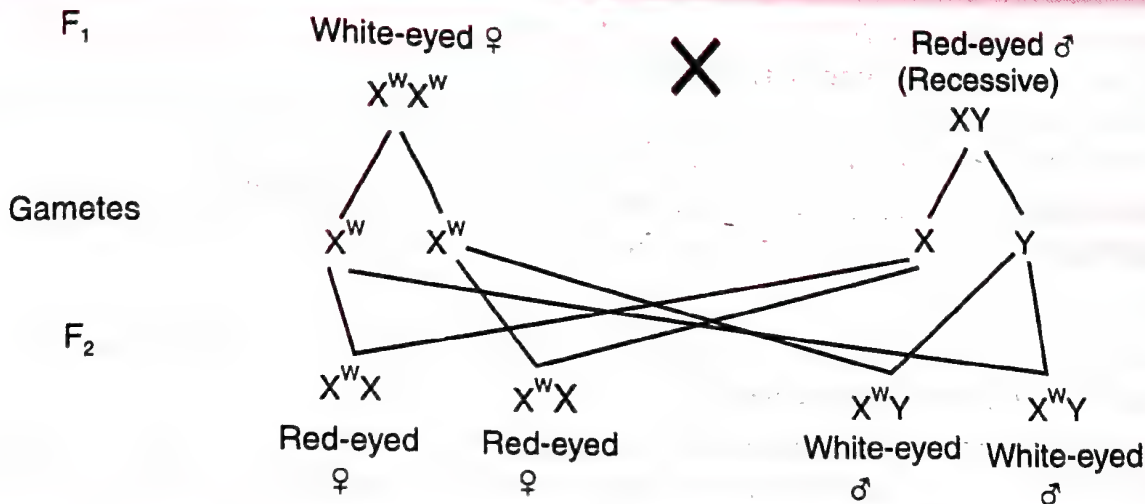


Fig. 5.41. A reciprocal cross between white-eyed female and red-eyed male produces males all white eyed and females all red-eyed.

(iii) **White-eyed Female \times Red-eyed Male.** Morgan then crossed F_1 white-eyed female ($X^W X^W$) with red-eyed male (XY). In F_2 generation, all females were red-eyed ($X^W X$) and all males were white-eyed ($X^W Y$).

Characteristics of Sex Linked Inheritance

1. It is criss-cross inheritance. Father does not pass the sex-linked allele of a trait to his son. The same is passed to the daughter, from where it reaches the grandson, *i.e.*, **diagnic**. It is because the males have only one X-chromosome which is transferred to the female offspring. Only Y-chromosome of the father is transferred to the male offspring but this sex chromosome does not carry many alleles.

2. Mother passes the alleles of a sex-linked traits to both sons and daughters.
3. Majority of the sex linked traits are recessive.
4. Sex linked traits are more apparent in males than in females.
5. As many sex-linked traits are harmful, males suffer more from sex-linked disorders.
6. Females generally function as carriers of sex-linked disorders because recessive genes can express themselves in females only in the homozygous state.

7. Traits governed by sex-linked **recessive genes** (a) Produce disorders in males more often than in females. (b) Express themselves in males even when represented by a single allele because Y-chromosome does not carry any corresponding alleles. (c) Seldom appear in both father and son. (d) Fail to appear in females unless their father also possesses the same and the mother is a carrier. (e) Females heterozygous for the trait function as carrier. (f) Female homozygous for the recessive trait, transfer the trait to all the sons.

8. Traits governed by sex-linked **dominant genes** (a) Produce disorders in females more often than in males. (b) All the female offspring will exhibit them if father possesses the same. (c) Do not get transmitted to son if mother does not exhibit them.

Criss Cross Inheritance

It is a type of sex linked inheritance where a parent passes the traits to the grand child of the same sex through offspring of the opposite sex, that is, father passes the traits to grandson through his daughter (**diagynic**) while the mother transfers traits to her grand daughter through her son (**dia-andric**). It was first studied by Morgan (1910) in case of eye colour in *Drosophila*. Criss-cross inheritance is applicable to most sex-linked disorders in humans, e.g., red green colour blindness, haemophilia.

Importance of Criss Cross Inheritance. (i) Any trait that shows criss-cross inheritance is located on the sex chromosome. (ii) Knowledge of criss-cross inheritance is useful in knowing the past, present and future transmission of sex-linked disorders. (iii) Discovery of criss-cross inheritance proved that genes are located in the chromosomes.

Besides criss-cross inheritance sex-linked inheritance can be **holandric** (from father to son, e.g., hypertrichy, maleness) and **hologynic** (from mother to daughter).

Sex Limited Characters

They are autosomal traits which are expressed in a particular sex in response to sex hormones though their genes also occur in the other sex.

Examples. Milk secretion in mammalian females, pattern baldness in males. The gene for baldness behaves as an autosomal dominant in males and autosomal recessive in females.

Sex Influenced Traits

The traits are not due to particular genes but are by-products of sex hormones.

Examples. Low pitched voice, beard, moustaches in males. In males, pattern baldness is related to both autosomal genes as well as excessive secretion of testosterone.

Differences between Autosomal and Allosomal Genes	
Autosomal Genes/Traits	Allosomal/Sex Linked Genes/Traits
1. There are always two alleles in both the sexes.	1. Males have a single allele while females have two alleles.
2. Reciprocal crosses yield same result.	2. Reciprocal crosses produce different results.
3. Inheritance is direct from parents to offspring.	3. Inheritance is mostly criss-cross, diagynic (through daughter to grandson) and diandric (through son to grand daughter).
4. Single recessive allele does not express its effect.	4. Single recessive allele expresses its effect in males. There is no effect in females.
5. Both the sexes are equally influenced by harmful alleles.	5. Males are affected more than the females.
6. A dominant allele influences both the sexes equally.	6. A dominant allele influences females more than the males.

CROSSING OVER AND RECOMBINATION

Let us first define recombination. Recombination is new arrangement of genes present in offspring that is different from those of parents due to independent assortment, crossing over and random combination during fertilization. Thus it is clear from its definition that the recombination may be caused by crossing over. Here, crossing over is mainly discussed.

Discovery

Janssens (1909) was the first person to discover chiasma (pl. chiasmata) formation during the prophase of meiosis-1. He, therefore, proposed **chiasma type hypothesis** for crossing over. **Morgan** (1910) found that chiasmata formation leads to crossing over of alleles by breaking and reunion of homologous chromosomes. Later, it was observed that crossing over of alleles occurs between almost all homologous chromosomes during meiosis.

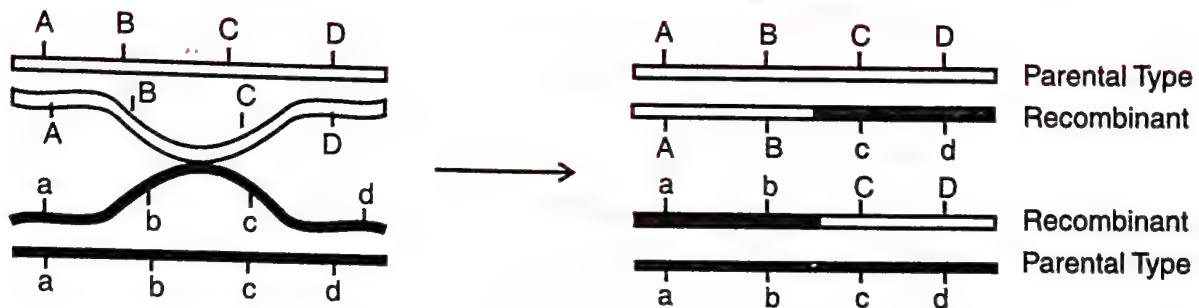


Fig. 5.42. Parental and Recombinant types after crossing over.

Definition of Crossing Over

Crossing over is the mutual exchange of segments between non-sister chromatids of homologous chromosomes in the pachytene of meiosis-I, producing new combinations of alleles of the linked genes.

The nonsister chromatids in which exchange of segments has occurred are called **recombinants** or **cross-overs** while the other chromatids in which crossing over has not taken place are known as **parental chromatids** or **non cross-overs**.

Mechanism of Crossing Over

Chromosomes get replicated in S-phase of interphase. Therefore, leptotene chromosomes are double stranded though the two strands are not visible due to presence of nucleoprotein complex in between the chromatids.

(i) **Synapsis.** Replicated but apparently single homologous chromosomes come to lie side by side with similar gene loci of the two chromosomes exactly opposite. It occurs in the zygotene stage of prophase-I. The phenomenon is called synapsis. The synapsed pairs of homologous chromosomes are called **bivalents**. The small amount of unreplicated chromosome (0.3%), if present, also undergoes replication (Stern and Hotta, 1973). The two homologous chromosomes are held together by a synaptonemal complex.

(ii) **Tetrad Formation.** Soon after completion of synapsis, the cell enters **pachytene** stage. Each of the homologous chromosome in a bivalent splits longitudinally into two sister chromatids. Thus, the bivalent now consists of four chromatids and is known as **tetrad**.

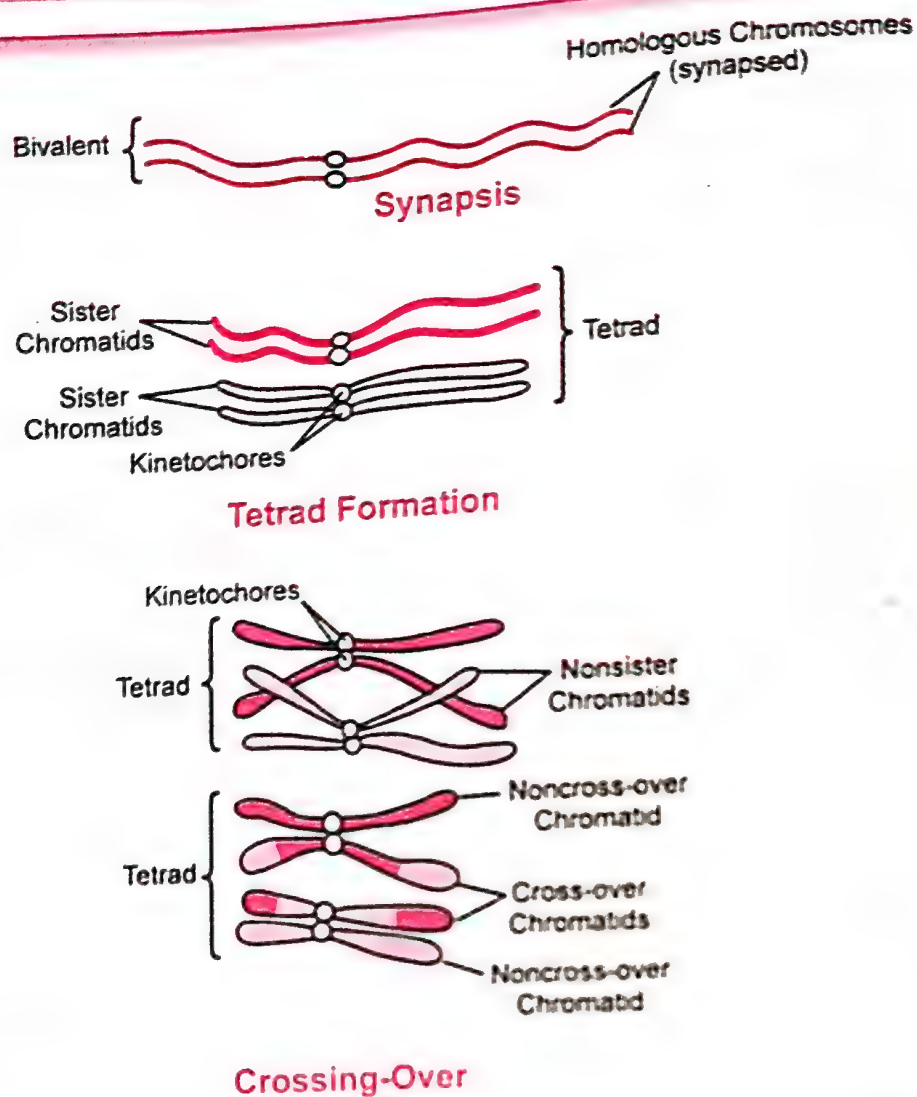


Fig. 5.43. Mechanism of crossing over. It produces 50% parental and 50% recombinant chromatids.

(iii) **Crossing over and Chiasma Formation.** It occurs in the pachytene stage. The non sister chromatids remain in contact at one or more points. These points of contact are known as **chiasmata** (sing. chiasma). There is breakage of chromatid segment and then rejoin with the exchange of segments of two non sister chromatids. After the completion of crossing over, the homologous chromosomes move apart.

Types of Crossing Over

Crossing over can be single, double or multiple.

(i) **Single Crossing Over.** Crossing over occurs at one point between two nonsister chromatids of a homologous chromosome pair. There are two parental types and two recombinants.

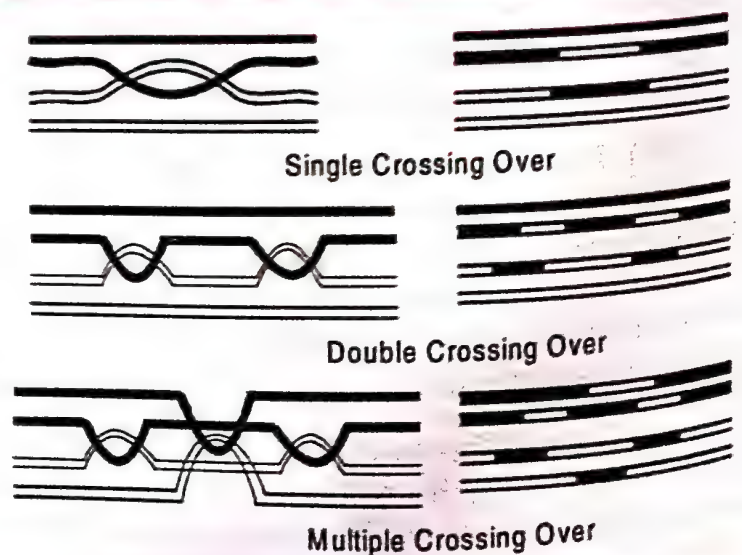


Fig. 5.44. Types of crossing over.

(ii) **Double Crossing Over.** Crossing over occurs at two points in a homologous pair of chromosomes. (a) **Reciprocal Double Crossing Over.** Two points of crossing over occur between the same nonsister chromatids. (b) **Complementary Crossing Over.** The two crossing overs involve three or all the four chromatids so that the number of cross overs is three or four with occurrence of one or no parental type.

(iii) **Multiple Crossing Over.** Three or more points of crossing over occur in the same homologous chromosome. Double cross-overs and parental types may or may not occur.

Factors Influencing Crossing Over

1. **Distance.** The physical distance between two genes determines the frequency of the crossing over between two genes. The frequency of crossing over increases with the increase in the physical distance between the two genes.

2. **Age.** Increase in age decreases the degree of crossing over in most of the cases.

3. **Sex.** Male *Drosophila* shows little crossing over. The phenomenon of crossing over is quite common in the female fly. Negligible crossing over is also reported in one sex of some other heterogametic organisms.

4. **X-Rays.** Exposure to X-rays increases the incidence of crossing over. Whittinghill produced a number of cross-overs in male *Drosophila* with the help of X-rays.

5. **Temperature.** Variations in temperature increase the frequency of crossing over.

6. **Heterochromatin.** Presence of centromere and heterochromatic areas (e.g., near telomere) decrease the rate of crossing over.

7. **Chemicals.** A number of chemicals present in the food have been found to change the degree of crossing over in animals.

8. **Interference.** One cross-over reduces the occurrence of another crossing over in its vicinity. The phenomenon is called interference. **Coincidence** is the ratio of observed double cross over in relation to expected double cross-over on the basis of noninterference or independent occurrence. Coincidence is small when interference is high.

Importance of Crossing Over

1. Crossing over is a means of introducing new combinations of genes and hence traits.

2. It increases variability which is useful for natural selection and under changed environment.

3. Since the frequency of crossing over depends upon the distance between the two genes, the phenomenon is used for preparing linkage chromosome maps.

4. It has proved that genes lie in a linear fashion in the chromosome.

5. Breeders have to select small or large population for obtaining the required cross-overs. For obtaining cross-overs between closely linked genes, a very large population is required.

6. Useful recombinations produced by crossing over are picked up by breeders to develop useful new varieties of crop plants and animals. Green revolution has been achieved in India due to this selective picking up of useful recombinations. Operation flood or white revolution is also being carried out on the similar lines.

Differences between Linkage and Crossing Over

Linkage	Crossing Over
<ol style="list-style-type: none"> 1. It is tendency of genes in a chromosome to remain together and pass as such to the next generation. 2. It produces parental types. 3. Strength of linkage between two genes increases if they are closely placed in a chromosome. 4. With increase in age, linkage increases. 5. It helps to maintain a newly improved variety. 	<ol style="list-style-type: none"> 1. It is exchange of genes/chromosomal parts to break established linkages and formation of new linkages. 2. It produces recombinations. 3. Frequency of crossing over between two genes decreases if they are closely placed. 4. Crossing over decreases with age. 5. It is the source of variations for producing new varieties.

LINKAGE MAPS OR CHROMOSOME MAPS

Definition. A linkage or genetic or chromosome map is a linear graphic representation of the sequence and relative distances of the various genes present in a chromosome. It resembles a linear road map that depicts all the important stations and the relative distances among them without actually depicting the exact mileage. The first chromosome maps were prepared by Sturtevant in 1911 for two chromosomes and in 1913 for all the four chromosomes of *Drosophila*.

Basis for Chromosomes Mapping. (i) Genes present in a chromosome are arranged in a linear sequence. (ii) The frequency of crossing over and hence recombination between two genes is directly proportional to the physical distance between the two. In other words, two genes which are nearest to each other in the chromosome will have least crossing over or recombination between them. On the other hand two genes which have the maximum distance between them on the chromosome will have the maximum percentage of crossing over or recombination. Therefore, relative distance between genes is indicated by the percentage of their recombination or crossing over. Because of the latter, chromosome maps are also called **cross-over maps**.

Map Units. 1% crossing over between two linked genes is known as 1 map unit or **centiMorgan (cM)**. 100% crossing over is termed as **Morgan (M)** and 10% crossing over as **deciMorgan (dM)** ; after T.H. Morgan who is considered to be the **father of experimental genetics**).

Example 1. A number of double crosses were made in fruitfly *Drosophila melanogaster* between normal flies and flies having recessive gene *sc* (scute or certain bristles missing), *ec* gene (echinus or rough eyes) and *cv* gene (cross veinless or absence of cross veins on wings). The characters are sex linked so that their genes are found on X- chromosome. The frequency of crossing over or recombination of these three sex linked genes was found to be

<i>sc</i> and <i>ec</i>7.6%
<i>ec</i> and <i>cv</i>9.7%
<i>sc</i> and <i>cv</i>17.3%

Therefore, the X-chromosome of the fruitfly contains gene *sc* at one end, gene *ec* at a distance of 7.6 map units or centimorgans from it, gene *cv* at a distance of 9.7 map units

or centimorgans from *ec* and 17.3 centimorgans from *sc*. It also proved that *cv* lies at the other end while *ec* occurs between *sc* and *cv*.

Example 2. Morgan and Sturtevant obtained recombination frequencies between (i) Black body (*b*) and vestigial wings (*vg*) to be 18% (ii) Black body (*b*) and cinnabar eye (*cn*) to be 9% (iii) Cinnabar eye (*cn*) and vestigial wings (*vg*) to be 9.5%.

<i>b</i> and <i>vg</i>18%
<i>b</i> and <i>cn</i>9%
<i>cn</i> and <i>vg</i>9.5%

Therefore, gene *b* occurs at one end of the chromosome, gene *cn* at a distance of 9 centimorgans from it while *vg* lies at a distance of approximately 9.5 centimorgans from *cn* and 18 centimorgans from *b*. Gene *cn* thus comes in between *b* and *vg*.

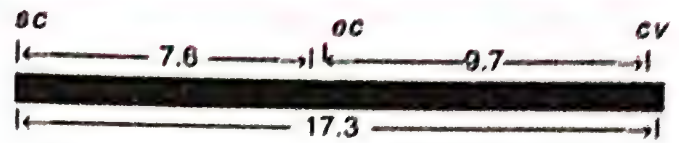
Example 3. If map distance between genes *A* and *B* is 3 units, between *B* and *C* 10 units, and between *C* and *A* to be 7 units the order of the genes on the linkage map can be found out as follows.

B cannot lie on the same side of *C* because the distance between *B* and *C* would then become 4 units (7–3) as against 10 centimorgans. Therefore, it must lie on the opposite side of *C* with *A* present in between the two, at a distance of 3 units from *B* and 7 units from *C*.

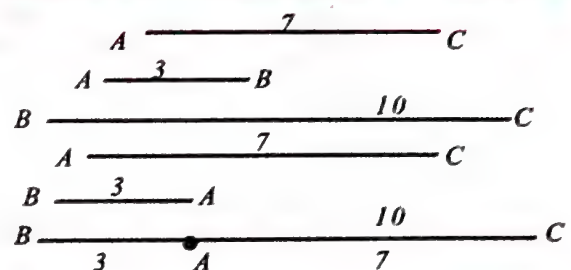
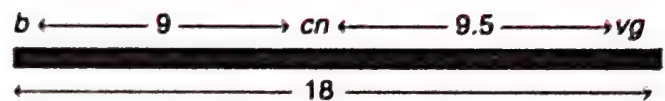
Accuracy. Linkage chromosome maps do not exactly depict the physical distance amongst genes because (i) Interference of one cross-over to the occurrence of another near it by reducing its frequency. Interference does not extend beyond the centromere. It also decreases with the increase in the distance. (ii) Heterochromatin reduces the incidence of crossing over. For example, the gene purple in chromosome 2 of *Drosophila melanogaster* lies at 0.4 map unit from centromere out of the total 55 map units while its actual distance is one quarter of the space between the centromere and chromosome end. (iii) Frequency of crossing over shows an extra increase from middle towards the end of chromosome.

Importance. Chromosome maps are important in knowing :

- The location of different genes in specific chromosomes.
- Occurrence of genes in a linear sequence on the chromosome.
- The order or sequence of genes in a particular chromosome.
- The strength of the linkage between two genes and the chances of their recombination.
- Predicting the effect of loss of chromosome segment.



Development of linkage chromosome map for three genes on the basis of their crossing over or recombination frequency in *Drosophila*.



- (vi) Predicting result of breeding experiments.
- (vii) Predicting the number of cross-overs present in a given population.
- (viii) Position where chromosome surgery is to be performed for genetic manipulation.

SEX DETERMINATION

Establishment of male and female individuals or male and female organs of an individual is called sex-determination.

Mechanisms of Sex-determination

Three methods of sex-determination are found in animals — Environmental, Nonallosomic or nonchromosomal and Allosomic or chromosomal.

1. **Environmental Sex-determination.** In various animals sex-determinal is based purely on environmental factors, some important factors are — (i) association with females, (ii) egg size and (iii) incubation temperature.

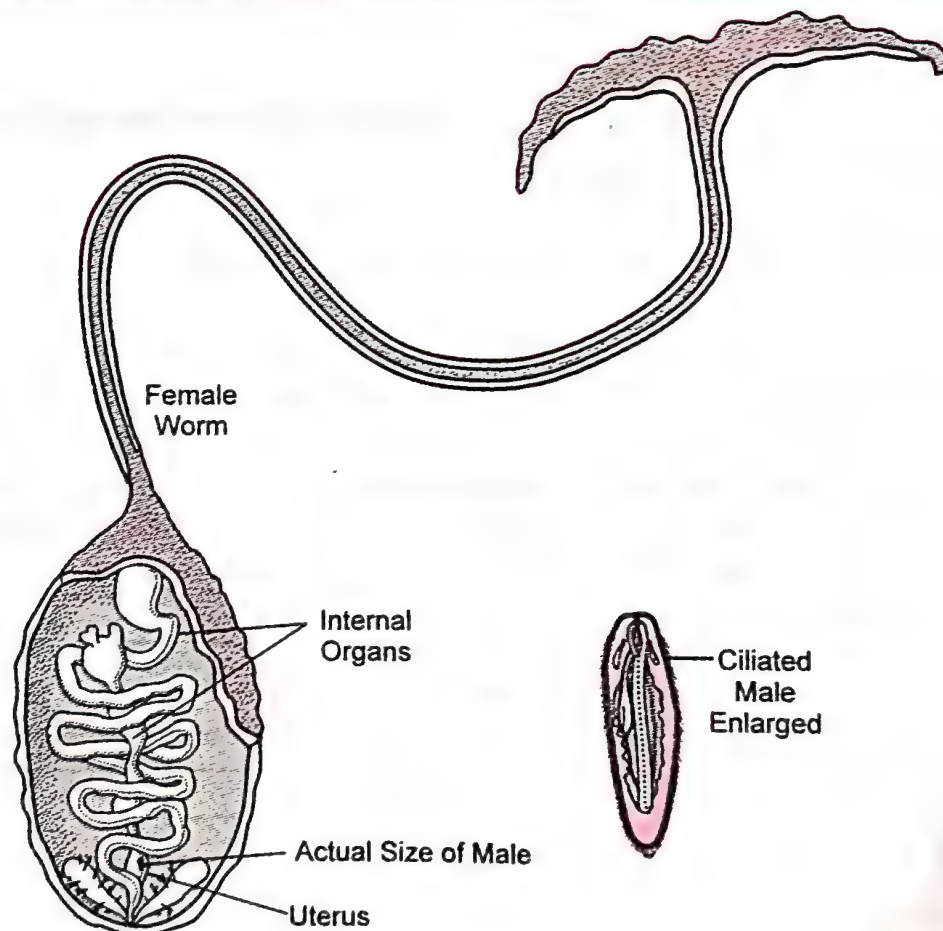


Fig. 5.45. Female and male of the marine worm *Bonellia viridis*. The male is shown in the uterus of the female and is greatly enlarged at the right side.

(i) **Association with Females.** The larva of sea worm *Bonellia* (an annelid) is sexually undifferentiated. Any larva coming in contact with the already grown female, develops into small male and enters the body of female and lives as a parasite in the uterus of female. In contrast, the larva that does not attach to female worm and remains free-living develop into a larger female (Baltzer, 1935). Coe (1943) also observed similar behaviour in marine

mollusc *Crepidula* where larva develops into male in the company of female and forms female if left alone.

(ii) **Egg Size.** In another sea worm, *Dinophilus*, the size of eggs, determines the sex of developing animals. Relatively larger sized eggs develop into females, while comparatively smaller sized eggs form males.

(iii) **Incubation Temperature.** In some animals like turtles, alligators and crocodiles, the temperature of egg incubation has a significant effect on the sex of developing embryos. In turtles, males are predominant below 28°C , females above 33°C (Fig. 5.46) and equal number of the two sexes between $28-33^{\circ}\text{C}$. In American alligator the temperature of egg incubation, 30°C or below produce females and 34°C or above males (Fig. 5.47). In crocodiles high temperature induces maleness and low temperature femaleness.

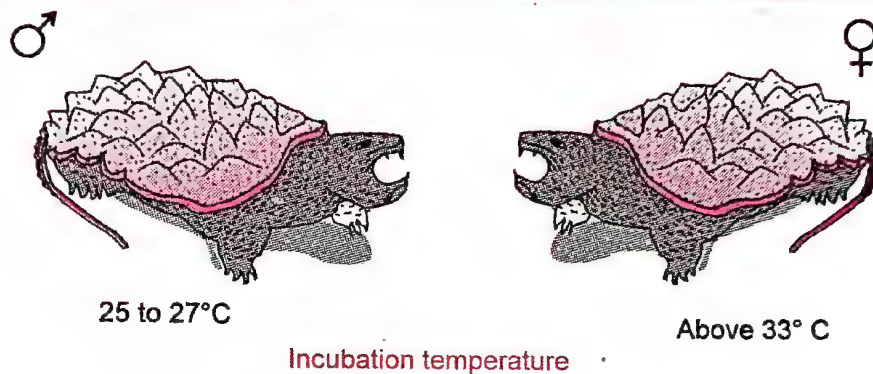


Fig. 5.46. Sex-determination in turtles.

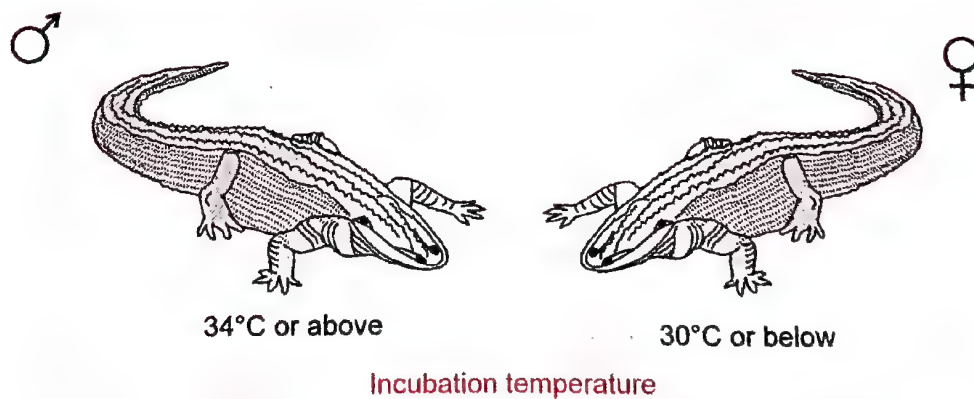


Fig. 5.47. Sex-determination in American alligator.

2. **Non-allosomic or Non-chromosomal Sex-determination.** In some primitive forms, sex chromosomes are not found. The sex determining factor or gene is located on some autosomes. For example, sex factor or fertility factor in bacteria is present on F-plasmid. Bacterial cells with fertility factor behave as male or donor cells and those without F-factor behave as female or recipient cells. In *Chlamydomonas*, the genes controlling (+) and (-) behaviour are present on autosomes. In Maize sex chromosomes are absent. The development of male and female inflorescence is controlled by genes present on autosomes.

3. **Allosomic or Chromosomal Sex-determination.** In majority of diploid and uni-sexual animals, the sex of the individual is determined by specific chromosomes. These

chromosomes are called **sex chromosomes** or **allosomes** (Gk. *allos* – other, *soma* – body) or **idiochromosomes** (Gk. *idios* – distinct, *chroma* – colour). A sex chromosome that determines male sex is termed **androsome** (Gk. *ander* – male, *soma* – body), e.g., Y-chromosome in humans. The normal chromosomes, other than the sex chromosomes if present, of an individual are known as **autosomes**. Sex chromosomes may be similar in one sex and dissimilar in the other. The two conditions are respectively called **homomorphic** (= similar, e.g., XX, ZZ) and **heteromorphic** (= dissimilar, e.g., XY, ZW). Individuals having homo-

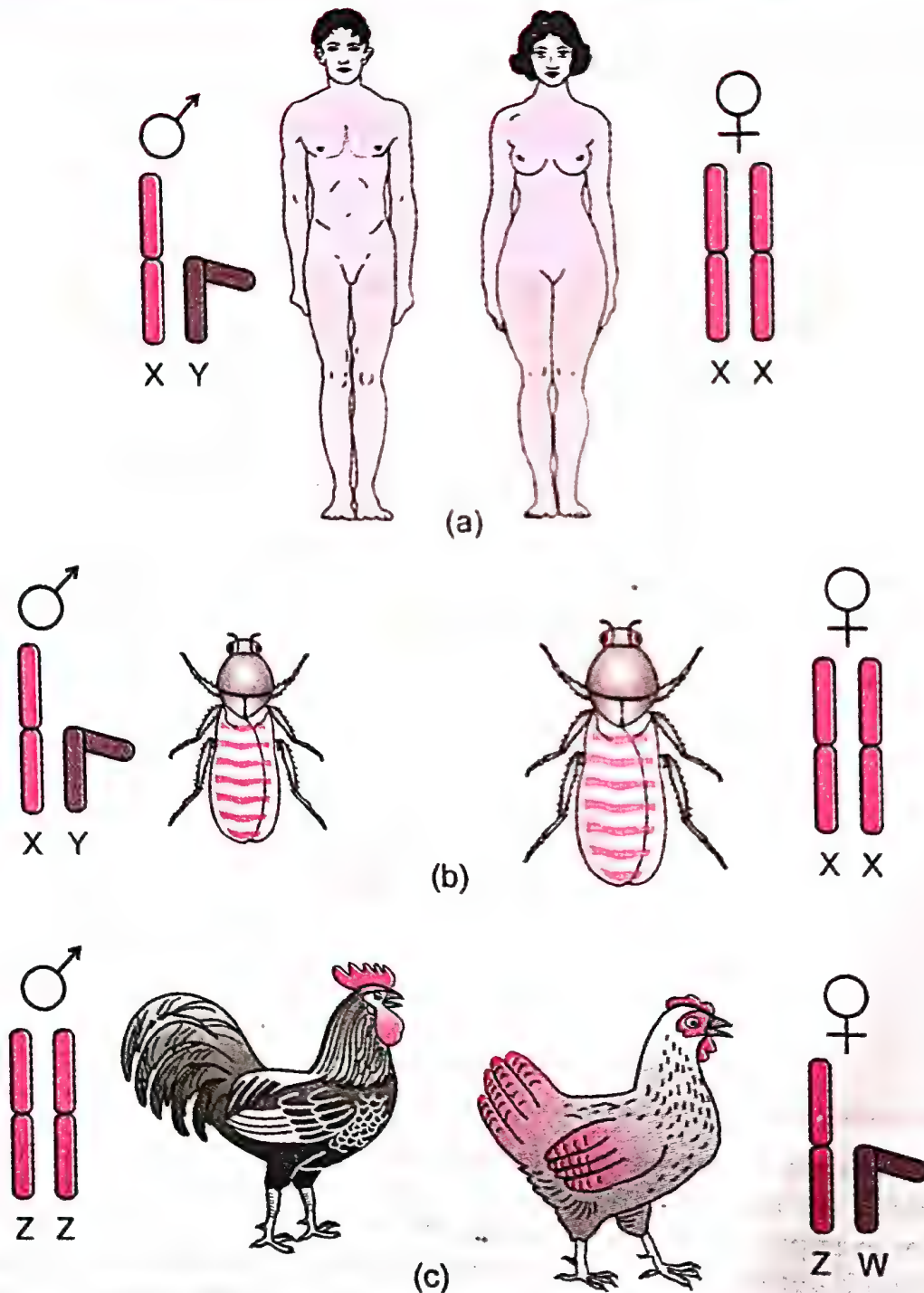


Fig. 5.48. Sex-determination by chromosomal differences. (a, b) Both in humans and in *Drosophila*, the female has a pair of XX chromosomes (homogametic) and the male XY (heterogametic) composition. (c) In many birds, female has a pair of dissimilar chromosomes ZW and male two similar ZZ chromosomes.

homomorphic sex chromosomes produce only one type of gametes. They are, therefore, called **homogametic** (e.g., human female). Individuals having heteromorphic sex chromosomes produce two types of gametes (e.g., X and Y containing). They are termed as **heterogametic** (e.g., human male).

Discovery

- (i) **Henking** (1891) discovered an **X-body** in 50% of the sperms of firefly.
- (ii) **Y-body** was discovered by **Stevens** (1902).
- (iii) **McClung** (1902) observed 24 chromosomes in female Grasshopper and 23 chromosomes in male Grasshopper.
- (iv) **Wilson and Stevens** (1905) put forward **chromosome theory of sex** and named the X- and Y- bodies as sex chromosomes, X and Y.

Heterogametes. Chromosomal or allosomic determination of sex is based on **heterogametes** or occurrence of two types of gametes in one of the two sexes.

(i) **Male heterogamety.** Males produce two types of sperms and females produce only one type of eggs, e.g., XX–XY type, found in *Drosophila* and humans.

(ii) **Female heterogamety.** Females produce two types of eggs and males produce only one type of sperms. e.g., ZW–ZZ type, found in birds.

Differences between Male and Female Heterogamety	
Male Heterogamety	Female Heterogamety
<ol style="list-style-type: none"> 1. Male produces two types of sperms, androsperms and gynosperms. 2. Female forms only one type of ova. 3. Only the male has two types or heteromorphic sex chromosomes. Example. Humans 	<ol style="list-style-type: none"> 1. The male produces only one type of sperms. 2. Female forms two types of ova, female forming and male forming. 3. Only female has two types or heteromorphic sex chromosomes. Example. Birds

Types of Allosomic or Chromosomal Sex-determination

Chromosomal sex-determination is of 5 types — XX – XY type, XX–XO type, ZW–ZZ type, ZO–ZZ type and haploid-diploid mechanism of sex-determination (haplodiploidy).

1. **XX–XY Type (XX Female, XY Male).** In most insects including fruitfly *Drosophila* and mammals including human beings the females possess two homomorphic (= isomorphic) sex chromosomes, named XX. The males contain two heteromorphic (= heterochromatic) sex chromosomes, i.e., XY. The Y-chromosome is often shorter and heterochromatic (made of heterochromatin). It may be hooked (e.g., *Drosophila*). Despite differences in morphology, the XY chromosomes synapse during zygotene. It is because they have two parts, homologous and differential. Homologous regions of the two help in pairing. They carry same genes which may have different alleles. Such genes present on both X and Y chromosomes are **XY-linked genes**. They are inherited like autosomal genes, e.g., xeroderma pigmentosum, epidermolysis bullosa. The differential region of Y-chromosome carries only Y-linked or **holandric genes**, e.g., **SRY** (Sex-determining region Y), an intronless gene on Y chromosome, required to initiate testis development in human embryo. SRY produces

TDF (testis determining factor) which initiates testis differentiation and development of Sertoli cells. Other holandric genes are of hypertrichosis (excessive hairiness) on pinna, porcupine skin, keratoderma dissipatum (thickened skin of hands and feet) and webbed toes. Holandric genes are directly inherited by a son from his father. Genes present on the differential region of X-chromosome also find expression in males whether they are dominant or recessive, e.g., red-green colour blindness, haemophilia. It is because the males are hemizygous for these genes.

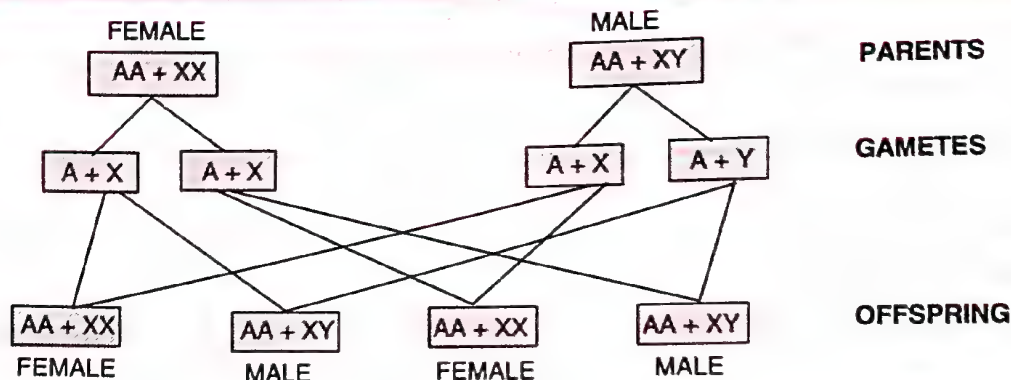


Fig. 5.49. XX-XY type of sex-determination.

2. XX—X0 Type (XX Female, X0 Male). In roundworms and some insects (true bugs, grasshoppers, cockroaches), the females have two sex chromosomes, XX, while the males have only one sex chromosome, X. There is no second sex chromosome. Therefore, the males are designated as X0. The females are homogametic because they produce only one type of eggs (A+X). The males are heterogametic with half the male gametes (gynosperms) carrying X-chromosome (A+X) while the other half (androsperms) being devoid of it (A + 0). The sex ratio produced in the progeny is 1 : 1 (Fig. 5.50).

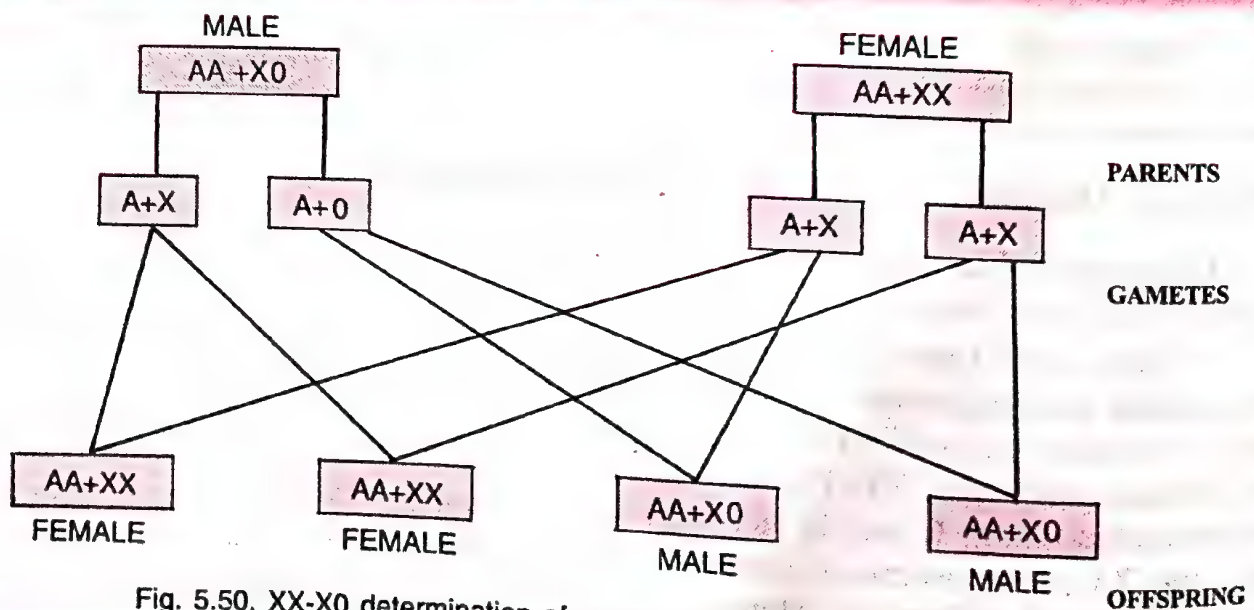


Fig. 5.50. XX-X0 determination of sex in Cockroach/Grasshopper.

3. ZW—ZZ Type (ZW Female, ZZ Male). In birds and some reptiles both the sexes possess two sex chromosomes but unlike human beings the females contain heteromorphic sex chromosomes (AA + ZW) while the males have homomorphic sex chromosomes (AA

+ ZZ). Because of having heteromorphous sex chromosomes, the females are heterogametic gametes or sperms are of one type (A + Z). 1 : 1 sex ratio is produced in the offspring (Fig. 5.51).

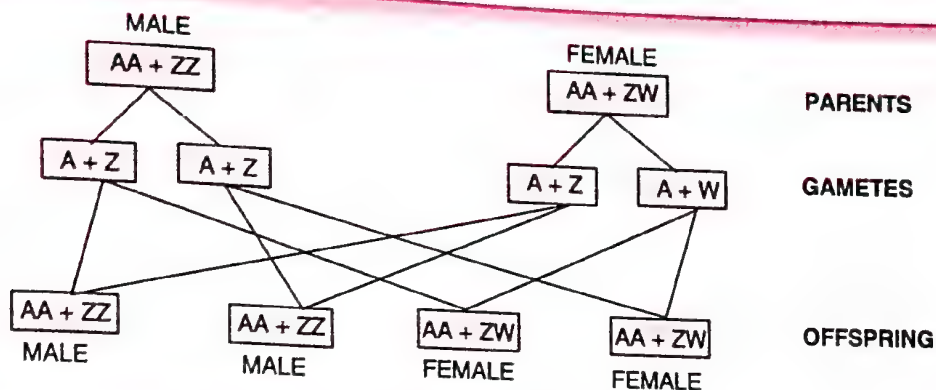


Fig. 5.51. ZW-ZZ determination of sex in chicken.

Differences in Sex Determination between Humans and Birds

Humans	Birds
1. Allosomes or sex chromosomes are XX-XY.	1. Allosomes or sex chromosomes are ZW-ZZ.
2. The sex chromosomes of females are homomorphic or similar, XX.	2. The sex chromosomes of females are heteromorphic or dissimilar, ZW.
3. The sex chromosomes of males are heteromorphic or dissimilar, XY.	3. The sex chromosomes of males are homomorphic or similar, ZZ.
4. The males are heterogametic while females are homogametic.	4. The males are homogametic while females are heterogametic.

4. **Z0 — ZZ Type (Z0 Female, ZZ Male).** This type of sex determination occurs in some **butterflies** and **moths**. It is exactly opposite the condition found in cockroaches and grasshoppers. Here the females have odd sex chromosome (AA + Z) while the males have two homomorphic sex chromosomes (AA + ZZ). The females are heterogametic. They produce two types of eggs, male forming with one sex chromosome (A + Z) and female forming without the sex chromosome (A + 0). The males are homogametic, forming similar types of sperms (A + Z). The two sexes are obtained in the progeny in 50 : 50 ratio (Fig. 5.52) as both the types of eggs are produced in equal ratio.

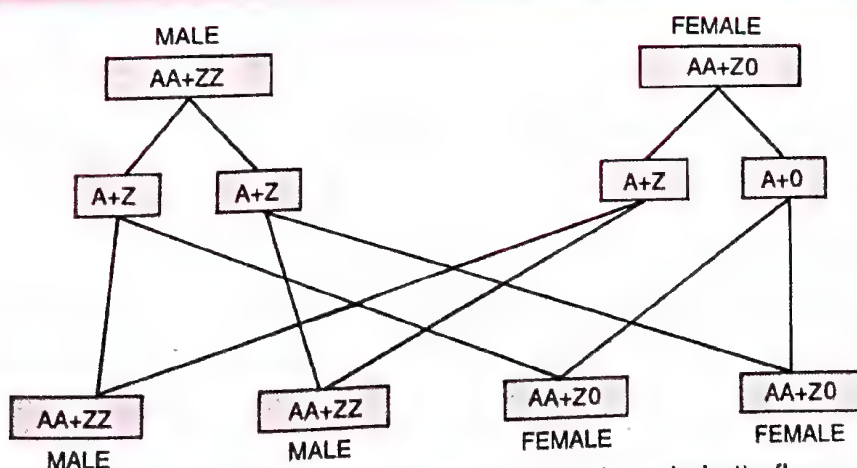


Fig. 5.52. Z0-ZZ determination of sex in butterfly.

Time of Sex-determination. In animals with 2 types of sperms, the sex of the offspring is determined at the time of fertilization by a chance event, i.e., by the kind of sperm that fuses with the ovum; whereas in animals with 2 types of eggs, the sex of the offspring is already fixed during meiosis before fertilization.

5. Haploid-Diploid Mechanism of Sex-determination (Haplodiploidy). It is a type of sex determination in which the male is haploid while the female is diploid. Haplodiploidy occurs in some insects like bees, ants and wasps. Male insects are haploid because they develop parthenogenetically from unfertilized eggs. The phenomenon is called **arrhenotoky** (Gk. *arrhen* – male, *tokos* – birth) or **arrhenotokous parthenogenesis**. Meiosis does not occur during the formation of sperms. Females grow from fertilized eggs and are hence diploid. Queen Bee picks up all the sperms from the drone during nuptial flight and stores the same in her seminal receptacle. Formation of worker bees (diploid females) and drones (haploid males) depends upon the brood cells visited by the queen.

While visiting the smaller brood cells, the queen emits sperms from its seminal receptacle over the eggs. As it visits the larger brood cells, it lays the eggs but the seminal receptacles fail to emit the sperms due to some sort of pressure on the ducts coming out of them. When a queen is to be formed the workers enlarge one of a small brood cell having fertilized egg and feed the emerging larva on a rich diet.

Males are normally fertile haploids due to development from unfertilized eggs. Occasionally diploid infertile males are also produced from heterozygous females through fertilization. Heterozygous females X^aX^z when crossed with normal males will produce two types of females, X^aX^m and X^zX^m . Fertilization with haploid males shall result in three types of individuals X^aX^m (female), X^zX^m (female) and X^mX^m (diploid male). The normal haploid males will, ofcourse, continue to be formed.

Genic Balance Theory of Sex

The theory of genic balance given by Calvin Bridges (1926) states that instead of XY chromosomes, sex is determined by the genic balance or ratio between X-chromosomes and autosome genomes. The theory is basically applicable to *Drosophila melanogaster* over which Bridges worked. He found that the genic ratio X/A of 1.0 produces fertile females whether the flies have $XX + 2A$ or $XXX + 3A$ chromosome complement. A genic ratio (X/A) of 0.5 forms a male fruitfly. This occurs in $XY + 2A$ as well as $XO + 2A$. It means that expression of maleness is not controlled by Y-chromosome but is instead localised on autosomes. The X-chromosomes, however, carry female determining genes like *Sxl*. Bridges further proposed that a genic ratio of less than 0.5 (e.g., $XY + 3A$ or $X/3A$) produces intersexes with a lot of morphological and sexual abnormalities. Sterile metafemales (super females) are produced with the genic ratio of 1.5 ($3X/2A$).

The sterile metamales and metafemales have been called **glamour boys and girls of fly world** by Dodson.

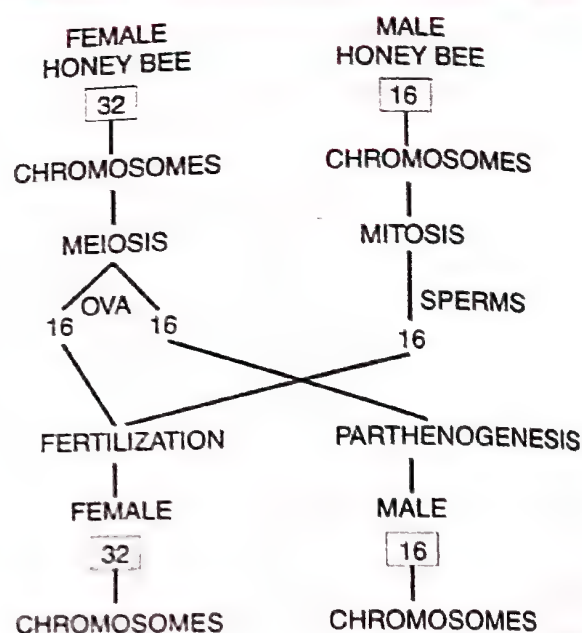


Fig. 5.53. Sex determination in Honey Bee.

Chromosome Complement	X / A Ratio	Sexual Morphology
X X X + 2A	3/2 or 1.5	Metafemale
X X X + 3A	3/3 or 1.0	Female
X X + 2A	2/2 or 1.0	Female
X X + 3A	2/3 or 0.67	Inter sex
X X X + 4A	3/4 or 0.75	Inter sex
XO + 2A	1/2 or 0.5	Male
XY + 2A	1/2 or 0.5	Male
XY + 3A	1/3 or 0.33	Metamale

Sex-determination in *Drosophila*

Drosophila has eight chromosomes, in which six are **autosomes**, common to both males and females. The fourth pair is of **sex chromosomes**. In males, these are represented by XY. Thus male *Drosophila* has 6 + XY chromosomes. In females, the sex chromosomes are XX and therefore, the total number of chromosomes are 6 + XX. Ova produced by the female are similar having 3 + X chromosomes, however, sperms produced by male are of two types— 3 + X and 3 + Y chromosomes. Thus male sex is **heterogametic** and the female sex is **homogametic**.

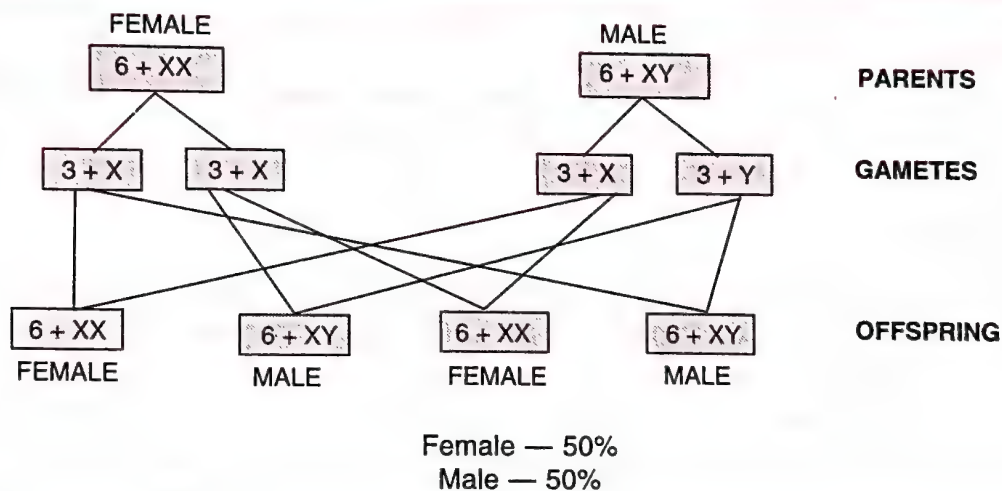


Fig. 5.54. Sex-determination in *Drosophila*.

Sex-determination in Humans

Human beings have 22 pairs of autosomes and one pair of sex chromosomes. All the ova formed by female are similar in their chromosome type (22 + X). Therefore, females are **homogametic**. The male gametes or sperms produced by human males are of two types, (22 + X) and (22 + Y). Human males are therefore, **heterogametic** (male digamety or male heterogamety).

Sex of Offspring (Fig. 5.55). Sex of the offspring is determined at the time of fertilization. It cannot be changed later on. It is also not dependent on any characteristic of the female parent because the latter is homogametic and produces only one type of eggs (22 + X). The male gametes are of two types, **androsperms** (22+Y) and **gynosperms** (22+X). They are produced in equal proportion. Fertilization of the egg (22 + X) with a gynospem

(22 + X) will produce a female child (44+XX) while fertilization with an androspERM (22 + Y) gives rise to male child (44 + XY). As the two types of sperms are produced in equal proportions, there are equal chances of getting a male or female child in a particular mating. As Y-chromosome determines the male sex of the individual, it is also called **androsome**.

Thus it is evident that it is the genetic makeup of the sperm that determines the sex of the child. However, it is unfortunate that in our society women are blamed for producing female children and have been ostracised and ill-treated because of this false notion.

In human beings, **TDF** of **SRY** gene of Y-chromosome brings about differentiation of embryonic gonads into testes. Testes produce testosterone that helps in development of male reproductive tract. In the absence of **TDF**, gonads differentiate into ovaries after sixth week of embryonic development. It is followed by formation of female reproductive tract. Female sex is, therefore, a **default sex**.

Sex Chromatin

Barr and Bertram (1949) found that interphase nuclei of human females stained with orcein possess small distinct chromatin body called **sex chromatin**, **Barr body** or **X-chromatin**. Barr body is found attached to nuclear envelope in oral mucosa, any where in the nucleus in nerve cells and as **drumstick** or small rod at one side of nucleus in neutrophil or polymorphonuclear leucocytes (Davidson and Smith, 1954). However, the occurrence is not cent per cent— 20–50% in cells of oral mucosa, 10% in neutrophil leucocytes, 85% in nervous tissue and 96% in amniotic and chorionic epithelium. Barr body is produced due to partial inactivation of one X-chromosome and development of facultative heterochromatin in it. Any of the two X-chromosomes can become heterochromatic. It begins in the late blastocyst stage (roughly 16th day of embryonic life), with germ cells being the last to develop one X-heterochromatisation. Heterochromatisation of one X-chromosome is maintained by a gene *Xist* (Penny *et al* 1996) which is expressed only in the inactive chromosome. Heterochromatisation of one X-chromosome provides for **dosage compensation** in females as it equalises the X-linked genes in the two sexes (males have only one X-chromosome). The X-chromosome is reactivated in meiotic prophase. The small arm of heterochromatic X-chromosome continues to bear active genes throughout. In embryo, placental cells show inactivation of paternal X-chromosome. In rest of the body, it is random— either paternal or maternal. It sometimes results in **mosaic pattern** of development, e.g., tortoise shell, female cats with black and brown patches over white background. Human females heterozygous for X-linked gene GPD, show equal number of erythrocytes with low and normal levels of glucose 6-phosphate dehydrogenase.

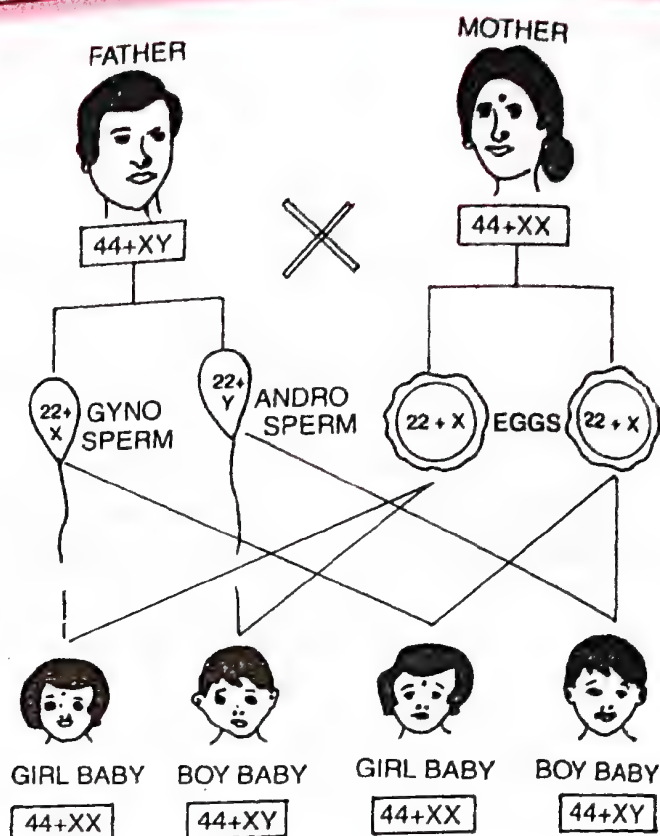


Fig. 5.55. Sex determination in humans and birth of a boy or girl baby.

Number of Barr bodies is one less than the number of X-chromosomes present in an individual, e.g., 1 for normal XX, 2 for XXX.

In males the cells stained with quinacrine mustard show fluorescent Y-chromatin because long arm of the Y-chromosome gets differentially stained. The number of Y-chromatins is equal to number of Y-chromosomes, e.g., 1 in XY and 2 in XYY.

GENETIC VARIATIONS

Genetic variations arise due to the two reasons— recombinations and mutations.

RECOMBINATIONS (New Combinations)

They are the reshuffling of parental genes and their linkages so as to produce new genotypes. Recombinations develop due to three reasons :

(i) *Independent assortment of chromosomes during meiosis or gamete formation.* Two pairs of chromosomes can assort in $2^2 = 4$ ways, 3 pairs in 2^3 ways, 7 pairs in 2^7 ways, 10 pairs in 2^{10} ways while 23 pairs of chromosomes can assort in 2^{23} or 8.6 million ways in the gametes; male (sperms) and female (eggs).

(ii) *Random fertilization or random fusion of gametes.* Any one of the possible gametes can combine with any other possible gamete of the other sex. Thus, if an organism possesses 2 pairs of chromosomes forming four types of gametes, $4 \times 4 = 16$ types of combinations can be produced in the offspring due to random fertilization. In human beings this possibility is $(8.6 \times 10^6) \times (8.6 \times 10^6)$ or 70×10^{12} combinations while the total human population is only around 6×10^9 .

(iii) *Crossing Over.* It occurs during pachytene of meiosis I. Crossing over forms new linkages due to mutual exchange of segments between nonsister chromatids of homologous chromosomes. It increases the number of recombinations by several millions.

MUTATIONS (L. *mutare* – to change)

Mutations are new sudden inheritable discontinuous variations which appear in the organisms due to permanent change in their genotypes. The term “mutation” was coined by Hugo de Vries (1901). Hugo de Vries also proposed mutation theory of evolution in his book “The Mutation Theory” published in 1903. Prior to Hugo de Vries, Darwin had proposed that evolution occurred due to continuous variations (or recombinations). The same is not possible because recombinations do not introduce new genes or alleles. Bateson (1894) hinted that evolution was due to large or discontinuous variations. Hugo de Vries proposed the same in the form of a theory. Hugo de Vries worked on *Oenothera lamarckiana* or Evening Primrose. Later workers have found that ‘mutations’ observed by Hugo de Vries were actually chromosome aberrations and polyploids. Real study of mutations began with Morgan (1910). Mutations bring about sudden and discrete changes in the germplasm or genetic material of the organisms. They add new variations in the populations and are the fountain head of evolution.

Types of Mutations

Mutations appearing in germinal cells are called **germinal mutations**. They are passed on to the offspring. Mutations appearing in the body cells (other than germinal) are known as **somatic mutations**. They generally die with the death of the body. Commonly somatic cells are not passed on to the progeny except when the mode of reproduction is asexual or

vegetative, e.g., Navel Orange (Brazil, 1820). Depending upon the cause, mutations are of two types—chromosomal and gene mutations.

CHROMOSOMAL MUTATIONS

These include genomic mutations (changes in chromosome number) and chromosomal aberrations (changes in chromosome structure).

1. Genomic Mutations — changes in chromosome number

They are of two types: polyploidy and aneuploidy.

(i) Polyploidy

It is the phenomenon of having more than two sets of chromosomes or genomes. Polyploidy occurs in nature due to the failure of chromosomes to separate at the time of anaphase either due to nondisjunction or due to nonformation of spindle. It can be artificially induced by application of colchicine or gronosan. An organism or its karyotype having more than two genomes is called **polyploid**. Depending upon the number of genomes present in a polyploid, it is known as triploid ($3n$), tetraploid ($4n$), pentaploid ($5n$), hexaploid ($6n$), etc. Polyploids with odd number of genomes (*i.e.*, triploids, pentaploids) are sexually sterile because the odd chromosomes do not form synapsis. They are, therefore, propagated vegetatively, e.g., Banana, Pineapple. Polyploids also do not cross-breed freely with diploids. They generally have a gigas effect at both morphological and biochemical levels due to increase in frequency of dominant alleles.

Polyploidy is of three types— autopolyploidy, allopolyploidy and autoallopolyploidy.

(a) **Autopolyploidy**. It is a type of polyploidy in which there is a numerical increase of the same genome, e.g., autotriploid (AAA), autotetraploid (AAAA). Some of the crop and garden plants are autopolyploids, e.g., Maize, Rice, Gram. Autopolyploidy induces gigas effect.

(b) **Allopolyploidy**. It has developed through hybridisation between two species followed by doubling of chromosomes (e.g., AABB). Allotetraploid is the common type. Allopolyploids function as new species, e.g., Wheat, American Cotton, *Nicotiana tabacum*. Two recently produced allopolyploids are *Raphanobrassica* and *Triticale*.

(c) **Autoallopolyploidy**. It is a type of allopolyploidy in which one genome is in more than diploid state. Commonly autoallopolyploids are hexaploids (AAAABB), e.g., *Helianthus tuberosus*.

(ii) Aneuploidy (Heteroploidy)

It is a condition of having fewer or extra chromosomes than the normal genome number of the species. Aneuploidy is of two types, **hypoploidy** or loss of chromosomes and **hyperploidy** or addition of chromosomes. The organisms showing aneuploidy are known as **aneuploids** or **heteroploids**. They are denoted by the number of affected chromosomes with the suffix —somic, e.g., nullisomic, monosomic, trisomic, etc. Aneuploidy commonly arises due to **nondisjunction** of the two chromosomes of homologous pair so that one gamete comes to have an extra chromosome ($N+1$) while the other becomes deficient in one chromosome ($N-1$). Fusion with similar or normal gametes gives rise to four types of aneuploids.

$$\begin{aligned}
 N \times (N - 1) &= 2N - 1 \\
 (N - 1) \times (N - 1) &= 2N - 2 \\
 N \times (N + 1) &= 2N + 1 \\
 (N + 1) \times (N + 1) &= 2N + 2
 \end{aligned}$$

Another method of obtaining aneuploidy is through loss of chromosomes from a normal or polyploid karyotype due to faulty mitosis.

Hyperploidy

(a) **Trisomic** ($2N + 1$). It has one chromosome in triplicate. Double trisomic has two different chromosomes in triplicate ($2N + 1 + 1$). Trisomics show a number of changes some of which are lethal. **Down's syndrome** is trisomic in origin where chromosome number 21 is in triplicate. Patau's syndrome is trisomy of 13th chromosome. Klinefelter's syndrome has an extra X-chromosome.

(b) **Tetrasomic** ($2N + 2$). It is aneuploid having one chromosome represented four times. Tetrasomics show more variability than trisomics. Both trisomics and tetrasomics are believed to have given rise to new species through secondary polyploidy, e.g., Apple, Pear.

Hypoploidy

(c) **Monosomic** ($2N - 1$). It is an aneuploid in which one chromosome is devoid of its homologue. Monosomic is generally weaker than the normal form. Turner's syndrome is a sex monosomic in human being ($44 + X$).

(d) **Nullisomic** ($2N - 2$). The aneuploid is deficient in a complete pair of homologous chromosomes. Nullisomics do not survive except amongst polyploids.

(e) **Mixed Aneuploids**. They are aneuploids with both hypoploidy and hyperploidy, e.g., $2N + 1A - 1B$.

2. Chromosomal Aberrations — Changes in Chromosome Structure

They are changes in the number and arrangement of genes in the chromosomes. Chromosome aberrations may involve changes in single chromosomes (intrachromosomal aberrations) or two chromosomes (interchromosomal aberrations). The aberrations are of several types. The important ones are as follows (Fig. 5.56).

Intrachromosomal Aberrations

(a) **Deficiency**. It is the loss of a terminal segment of a chromosome and is produced by a single break in the chromosome, e.g., ABCDEF/ABCDEFGH (segment GH missing).

(b) **Deletion**. It is the loss of an intercalary segment of a chromosome which is

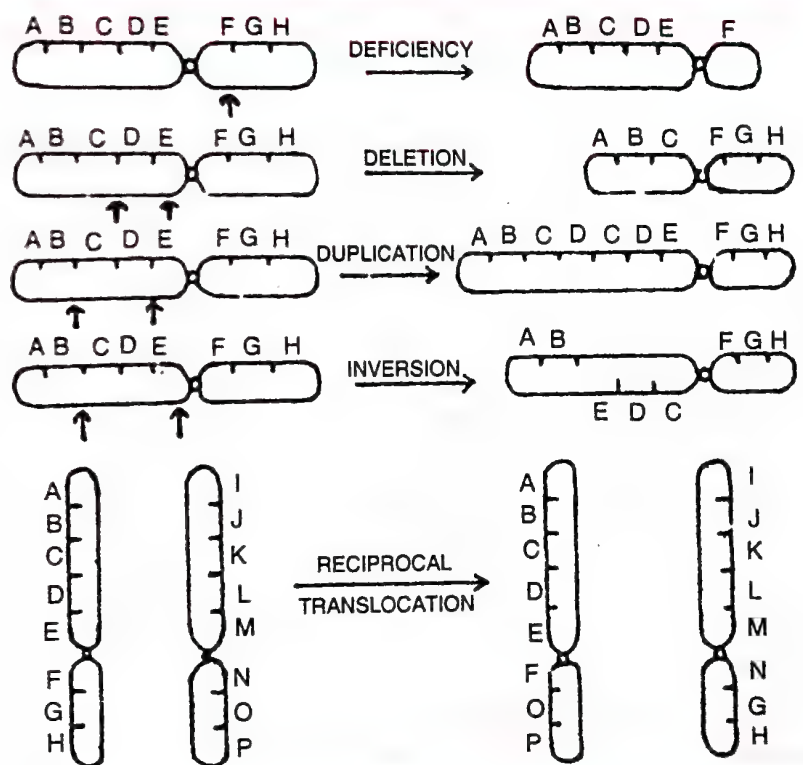


Fig. 5.56. Types of chromosomal aberrations.

produced by a double break in the chromosomes followed by the union of remaining parts, e.g., ABCFGH/ABCDEF~~GH~~ (segment DE missing).

Deficiency or deletion in a single chromosome can be known during synapsis of homologous chromosomes when certain segment of one chromosome remains unpaired or forms a loop. Notched wing margin in *Drosophila* is formed by deletion of a segment in X-chromosome. Cri-du-chat syndrome in humans is caused by deletion of a part of short arm of chromosome 5.

(c) **Inversion** (Fig. 5.57). It is a type of chromosome aberration in which part of the chromosome segment gets inverted by 180° . For example, chromosome ABCDEFGH develops inversion in the part CDE to form ABEDCFGH. Inversion involving centromere is called **pericentric**. Inversion occurring beyond a centromere is termed as **paracentric**. Inversion inhibits the chromosomal synapsis in the region of change. The non recombinant block is called **supergene**. Crossing over results in the formation of duplications, deficiencies, breaking of chromosome homologues into dicentric and acentric portions (paracentric inversion) resulting in sterility (50%), persistence of inversions (25%) and normal gametes (25%).

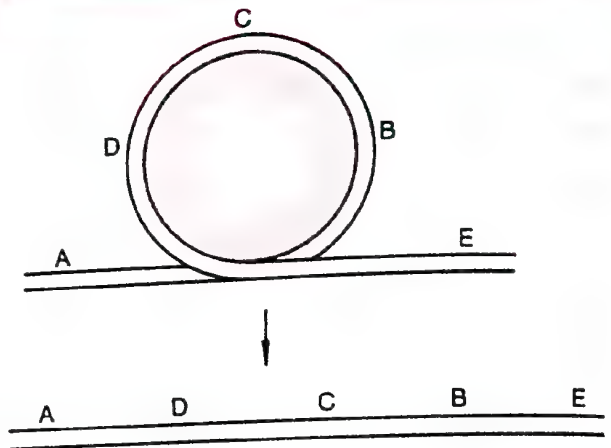


Fig. 5.57. Inversion through loop formation.

Interchromosomal Aberrations

(d) **Duplication**. It is the phenomenon of having an extra chromosome segment attached to its normal homologous chromosome so that a gene or set of genes is represented twice in the same chromosome, e.g., ABCDCDEFGH/ABCDEFGH (segment CD duplicated). If the new segment gets attached adjacent to the region of similar segment, the duplication is called repeat or tandem. A loop or buckle shall appear in the region of duplication if synapsis occurs between chromosome with duplicated segment and normal chromosome. Duplication increases the number of genes in the genotype. It increases genetic redundancy, protects the organism against harmful mutations and allows development of new traits. Sometimes duplication of a gene has a deleterious affect. For example, in *Drosophila* when the B gene for normal eye located on X-chromosome becomes duplicate, the eyes become smaller (Bar Eye).

(e) **Translocation**. It is the separation of a chromosome segment and its union to a nonhomologous chromosome. Translocation is of two types— simple and reciprocal. In reciprocal translocation two nonhomologous chromosomes exchange segments between themselves to create new linkage groups in both the chromosomes, e.g., ABCDEFOP/ABCDEF~~GH~~, IJKLMNGH/IJKLMN~~OP~~ (GH and OP segments get exchanged). Reciprocal translocation is also called illegitimate crossing over. In simple translocation one chromosome shows deletion or deficiency while a nonhomologous chromosome comes to have an additional segment.

Translocation produces imperfect or faulty pairing during meiosis. It produces duplication, deficiencies and wrong segregations of chromosomes resulting in sterility of a large section of gametes. However, translocation introduces new linkages which may change expression of some genes, e.g., recessive gene for hair becomes dominant in *Drosophila*. Whole arm translocation or centric fusion causes reduction in chromosome number. In

human beings chromosome number 2 has been formed by centric fusion of two chromosomes of primate ancestors. Myelogenous leukemia (chronic myeloid leukemia or CML) is caused by translocation of a part of long arm of chromosome 22 (Philadelphia chromosome) to chromosome 9.

GENE MUTATIONS

Gene mutation is the change in expression of a gene which is caused by change in number, sequence and types of nucleotides. When gene mutation occurs due to change in a single base pair of DNA, it is known as **point mutation**. When mutation is due to change in more than one base pair or entire gene it is called **gross mutation**. Most of the gene mutations develop due to errors in DNA replication. They are, therefore, also called **copy error mutation**.

Detection of Gene Mutation

Unlike the chromosomal mutations, the gene mutations are not observable under a microscope. Gene mutations are detected when they cause a noticeable change in the phenotype of the organisms. Most gene mutations are recessive and are, therefore, not immediately detected. Dominant mutations are rare. A dominant gene mutation causes the disease **aniridia** (lack or defect of iris) in humans.

Origin of Mutations

Mutations may arise spontaneously due to certain intracellular factors or be induced by environmental factors. The latter are called **mutagens**. The mutagens are extracellular physical, chemical or biological factors which can cause mutations or increase the frequency of mutations in organisms.

1. **Spontaneous Mutations.** They are mutations which occur randomly, naturally and automatically due to internal reasons without any relation to any external factor. Rate of spontaneous mutations varies from 1 in 2000 to 1 in several million divisions. The possible reasons are :

(i) **Background Radiations.** They occur naturally from various sources, e.g., sun, radioactive minerals. (ii) **Tautomers.** All the four nitrogen bases also occur in their tautomeric or isomeric states, forming either imino group ($-\text{NH}$, e.g., cytosine, adenine) instead of amino group ($-\text{NH}_2$) or enol group ($-\text{COH}$, e.g., thymine, guanine) instead of keto group ($=\text{CO}$). Tautomers pair with different bases so as to cause a change in the sequence like AT to CG. (iii) **Deamination of Cytosine.** Cytosine slowly deaminates to produce uracil like AT to CG. (iv) **Copy Error.** There are a which pairs with adenine resulting in change in base pairing. (iv) **Copy Error.** There are a number of steps involved in replication, transcription and translation. Any wrong choice or entry of different group will cause mutation. Most of the copy errors are corrected during proof reading but a few do escape correction.

2. **Induced Mutations.** They are mutations that are produced in response to specific external factors and chemicals. Muller (1927) was the first to produce induced mutations in *Drosophila* by exposing them to X-rays.

The mutagens that induce mutations may be physical, chemical or biological.

1. **Physical Mutagens.** They are of two types, temperature and high energy radiations.

(i) **Temperature.** Increase in temperature increases the rate of mutations with $Q_{10} = 5$, i.e., increases 5 times with every 10°C rise in temperature. Rise in temperature breaks the hydrogen bonding between the two strands of DNA and hence denatures the latter. It

disturbs the synthetic process connected with replication and transcription. In Rice, low temperature is known to increase the rate of mutations.

(ii) **High Energy Radiations.** They include neutrons, alpha particles, cosmic rays, gamma particles, beta rays, X-rays, ultra-violet rays, etc. Ultra-violet rays are nonionising radiations which affect DNA by forming thymine dimers. It causes bends in DNA duplex that bring about misreplication. Other high energy radiations are ionising radiations. They ionise DNA constituents that can react with several biochemicals. X-rays are known to deaminate and dehydroxylate nitrogen bases, form peroxides and oxidise deoxyribose. Muller (1927) was the first to induce mutations in *Drosophila* with the help of X-rays. He found 150 fold increase in the rate of mutations. Radiations emitted by nuclear fall-outs and the atom bombs dropped over Hiroshima and Nagasaki in Japan have caused many mutations.

2. **Chemical Mutagens.** They are of several types. The common ones are nitrous acid, alkylating agents, base analogues and acridines.

(i) **Nitrous Acid.** It is a deaminating agent which changes cytosine to uracil, guanine to xanthine and adenine to hypoxanthine. Hypoxanthine mispairs with cytosine. Therefore, A—T is replaced by H—C. Similarly C—G is replaced by U—A and C—X. These unusual or **forbidden base pairs** disturb replication and transcription. Incomplete or defective polypeptides are produced during translation.

(ii) **Alkylating Agents.** *Nitrogen mustards* [e.g., $\text{RN}(\text{CH}_2\text{Cl})_2$], diethyl sulphate (DES), dimethyl nitrosamine (DMN) and other alkylating agents cause methylation or ethylation of nitrogen bases. The latter fail to pair with normal partners as well as prevent separation of two DNA strands.

(iii) **Base Analogues.** They resemble the normal bases of DNA and, therefore, get incorporated into DNA in place of them. The common mutagens of this type are 5-bromouracil and 5-fluorouracil. They substitute for thymine of DNA and pair with guanine. Thus A—T is replaced by G—Bu or Fu. It disturbs replication, transcription and translation.

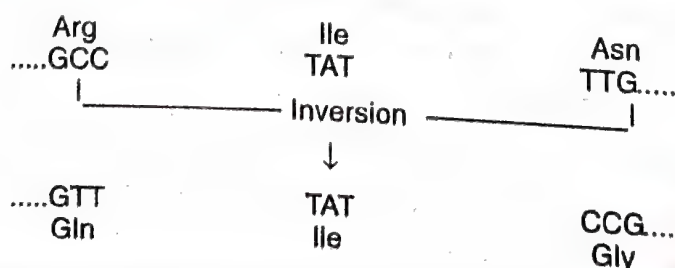
(iv) **Acridines.** They are tar derived heteroaromatic flat molecules from which a number of dyes and pharmaceuticals are prepared. Acridines (e.g., acriflavine, proflavine, euflavine, acridine orange) enter the DNA chains in between two base pairs and cause deletion or addition of a few nucleotides. The frame of nucleotide sequence of DNA will be thus disturbed and read differently. It is also known as **frame-shift** or **gibberish mutation**.

3. **Biological Mutagens.** Viruses take over the genetic machinery of the host cell. It involves change in structure and expression of genes resulting in mutation.

Methods of Gene Mutations

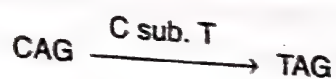
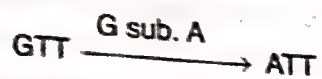
Gene mutations occur by three methods — inversion, substitution and frameshift.

1. **Inversion.** Base sequence of a DNA segment is reversed. The new sequence will naturally have different codons, e.g.,

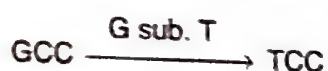
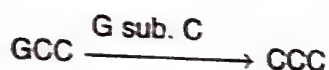
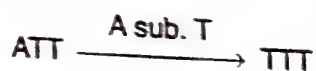
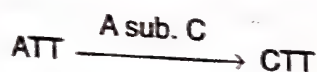


2. **Substitution (Replacement).** It involves replacement of one or more base pairs with others. Substitution is of three types.

(i) **Transition.** A purine is replaced by another purine (A with G or *vice versa*) while a substitution is changed with another pyrimidine (C with T or *vice versa*).



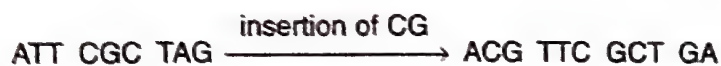
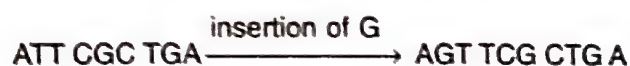
(ii) **Transversion.** There is replacement of a purine base (A, G) with a pyrimidine base (C, T) or *vice versa*.



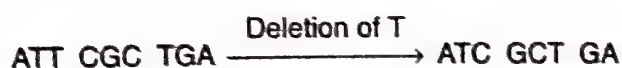
(iii) **Tautomerisation.** It is a reversible change in the location of hydrogen atom in a molecule that alters it from one to another isomer and bases exist in alternative valency status. Thymine and guanine are normally in *keto* forms, but when in the rare *enol* forms they can join by three hydrogen bonds with keto forms of guanine and thymine, respectively. Tautomeric shifts that modify the pairing of nucleotides can result in base substitutions and as a result mutations. **Tautomerism** is the phenomenon in which two isomeric forms of molecules exist in equilibrium.

3. **Frame-Shift Mutations.** Insertions and deletions of a base pair or base pairs in DNA are referred as frameshift mutations because this shifts the reading frame of codons from the site of change onward. A frame shift mutation usually completely inactivates the protein product of the gene. For example, human hereditary disease muscular dystrophy is caused by frameshift mutation. It is of two types.

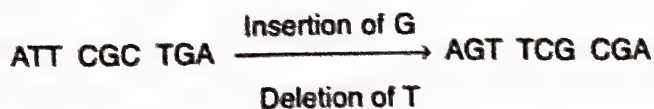
(i) **Insertion.** There is addition of one or more nucleotides inside the gene.



(ii) **Deletion.** One or more nucleotides slip out of gene changing the reading of the frame in backward deletion.



Both insertion and deletion of nucleotides may occur in the same gene.



Nonsense, Same-sense and Mis-sense Mutations. A **nonsense mutation** is the one which stops polypeptide synthesis due to formation of a terminating or nonsense codon, viz., ATT(UAA), ATC(UAG), ACT(UGA). A **mis-sense mutation** is the one which involves change in a codon that produces a different amino acid at the specific site in polypeptide, often resulting in its nonfunctioning. A **same-sense mutation** is silent mutation in which the codon is changed but the change does not alter the amino acid specificity (e.g., GCA → GCT or GCC or GCG).

Silent Mutation. A mutation that has no phenotypic effect is called silent mutation.

Point mutation. A gene mutation which involves change in a single base pair of DNA is called point mutation. Classical example of point mutation is sickle cell anaemia.

Gross Mutation. A gene mutation which involves more than one base pairs or entire gene is known as gross mutation.

Time of Occurrence of Gene Mutations. All types of gene mutations can potentially occur at the time of DNA replication when new DNA strands are synthesized.

Errors in DNA Replication are Necessary. In fact, replication of DNA should not be an error-free process. It is through the errors (mutations) that variability is introduced into a population, and without variability evolution cannot occur.

Relation between Chromosomal and Gene Mutations. Gene mutations result in chromosomal mutations because the genes are segments of the chromosomes. However, the reverse is not true. The chromosomes may mutate without a change in the individual genes.

- Unlike the chromosomal mutations, the gene mutations are not observable under a microscope. They are detected when they cause a noticeable change in the phenotype of the organisms.

- Generally one gene mutates at a time. Mass mutations are very rare.
- Mutations occur in both germ cells and somatic cells.
- A mutated gene may mutate back to the original wild type.
- Base Pair is a pair of nitrogenous bases, most commonly one purine and one pyrimidine that are connected through hydrogen bonds in a double stranded region of a nucleic acid molecule. The normal base pairs in DNA are A—T and G—C.

- Gene mutations form the raw materials for organic evolution.
- Atom bombs dropped over Hiroshima and Nagasaki (Japan) during second world war caused many induced mutations in Japanese people. Radiation causes some kinds of cancer.
- Chromosomal aberrations are commonly observed in cancer cells.

Importance of Mutations

1. **Variability.** Mutations are the source of all variability in a population. Variability increases the adaptability of the organism to its environment and wards off death or deterioration in an unfavourable environment.

2. **Study of Genes.** Unless and until a gene mutates and has a recessive or intermediate allele, it will remain unnoticed and its importance in the physiology and phenotype of the individual cannot be evaluated.

3. **Evolution.** Mutations are the fountain head of evolution. They add new variations in the populations. The variations allow some organisms to become better fitted in the struggle for existence. They, therefore, survive while others with less variations perish. The process

continues and the variations accumulate. It gives rise to new varieties, subspecies and species. Sometimes a single mutation gives rise to newer type of organisms, e.g., Ancon Sheep, Delicious Apple, Navel Orange, *Cicer gigas* (Giant Gram), *Arachis hypogea* var. *gigantia* (Giant Groundnut). Polyploidy has produced a number of new organisms. It has been induced artificially to obtain new species (e.g., *Triticale*) and better yield.

4. **Industrial Microbiology.** Workers are continuously developing newer mutant races of microorganisms for better fermenting ability (e.g., yeast), better yield of antibiotics (e.g., *Penicillium*) and several other biochemicals.

5. **Health Hazard.** Increasing use of mutagens exposes workers and other segments of population to hazards of having deleterious mutations. Therefore, some countries have already imposed restrictions and regulations on the use of mutagens. X-ray technicians and workers in atomic energy plants are always warned to be extra careful towards incidental exposure.

6. **Animal Husbandry.** There are several varieties of domesticated animals and pets. All of them have originated from the wild types through mutations. Some recent mutations include Ancon sheep, Hornless cattle, Hairless cat, etc. Mutations have also occurred for higher milk yield, lactation period, egg production, meat content, wool yield, adaptability to diverse environments. These useful mutations have been picked up by animal breeders.

7. **Agriculture.** Mutations have played an almost revolutionary part in agriculture both at the beginning of civilization as well as now in the improvement of agriculture to meet the needs of ever-growing human population.

(i) The domestication of several plants was made possible due to sudden mutations appearing in them, e.g., stiff ears in Wheat, Rice and other cereals, lint in cotton.

(ii) Cauliflower, Cabbage, Brussel's Sprout and Knol Kohl are all mutants developed from Wild Cabbage.

(iii) Plant breeders are using induced mutations for improvement of crop plants for higher yield, nutritive value, stiffness of straw, resistance to lodging, lesser duration of crop ripening, disease resistance, etc. For this purpose a gamma radiation plant is fitted in IARI, New Delhi. High yielding popular varieties of Mexican wheat were developed by Borlaugh through bringing together of dwarf mutants. They were originally red grained. The colour was not liked by the Indians. Their cultivation in India was made possible by the development of amber seed colour (e.g., Sharbati Sonora) through mutations.

(iv) The high yielding Rice variety called 'Reimei' was produced through gamma irradiation.

(v) Gustafson (1941, 1947) developed a number of varieties of Barley through induced mutations. The two common mutations in Barley are 'erectoides' and 'eceriferum'. Besides high yield, they combined many other useful characters like drought and disease resistance.

(vi) Reduction in the duration of crop plants without affecting yield has been one of the important contributions of mutations. Such mutations have been achieved in almost all crops including Sugarcane (18 months to less than 10 months), Castor (9 months to 4.5 months, e.g., Aruna variety).

(vii) In vegetatively propagated plants, mutations are the only source of improvement and development of variability. The induced mutations are somatic in nature. A somatic mutation in Banana has produced the variety Bhaskara where fruit size is 35 cm × 12 cm. Seedless Navel orange and seedless Grapes are somatic mutations. Somatic mutations have also helped improve Pineapple and Potato.

(viii) About 50% of the present day crop and horticultural plants have developed in nature through polyploidy, e.g., Wheat, Rice, Maize, Gram, Cotton, Potato, Sugarcane, Banana, Pineapple, Apple, Pear, etc.

(ix) A large number of mutations have been induced in ornamental plants in order to enhance their beauty, longer life and fragrance, e.g., *Dahlia*, *Rosa*, *Chrysanthemum*, *Papaver*.

PEDIGREE ANALYSIS

A record of inheritance of certain genetic traits for two or more generations presented in the form of a diagram or family tree is called pedigree. The individual from which a pedigree is initiated is called **proband** or **propositus** (propositus if male and propista if female). Pedigree is employed in case of human beings and domesticated animals, especially pets.

Problems in the study of Human Inheritance. These problems are as follows.

1. The generation time is long, 20 years or more.
2. A research worker can observe 3-4 generations in one's life time.
3. The number of offspring per couple is small.
4. Homozygous traits are very few.
5. Each marriage combines alleles from two different families.
6. Many of the human traits are governed by a number of genes.
7. Human chromosome number (46) is large.
8. Human beings cannot be subjected to experimentations like guinea pigs or edible pea.
9. Environment has a powerful impact on expression of traits.

Maintenance of pedigree can help the genetic counsellors to study the passage of genes from generation to generation.

Symbols used in Pedigree Analysis. In a pedigree a **square** represents the male, a **circle** the female, **solid** (blackened) symbol shows the trait under study or affected individual; unaffected or normal individual by an open or clear symbol and a cross or shade (of any type) in the symbol signifies the carrier of a recessive allele. Words can also be used in place of symbols. Parents are shown by **horizontal line** while **their offspring** are connected to it by a **vertical line**. The offspring are then shown in the form of a horizontal line below the parents and numbered with arabic numerals. Each generation is given a roman numeral and a separate row or horizontal line (Fig. 5.58).

Usefulness of Pedigree Analysis. Pedigree analysis is study of pedigree for the transmission of particular trait and finding the possibility of absence or presence of that trait in homozygous or heterozygous state in a particular individual. (1) It is useful for the genetic counsellors to advice intending couples about the possibility of having children with genetic defects like haemophilia, colour blindness, alkaptonuria, phenylketonuria, thalassemia, sickle cell anaemia (recessive traits), brachydactyly and syndactyly (dominant traits). (2) Pedigree analysis indicates that Mendel's principles are also applicable to human genetics with some modifications found out later like quantitative inheritance, sex linked characters and other linkages. (3) It can indicate the origin of a trait in the ancestors, e.g., haemophilia appeared in Queen Victoria and spread in royal families of Europe through marriages. (4) It can indicate the harm a marriage between close relatives, may cause.

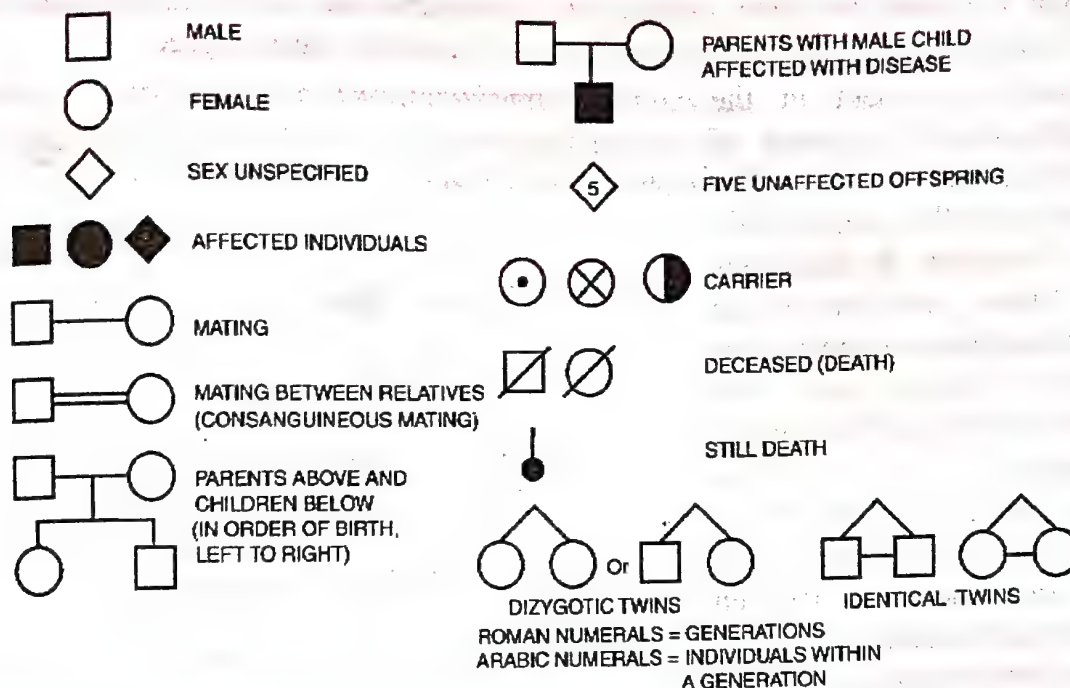


Fig. 5.58. Symbols for common human pedigree analysis.

Pedigree analysis employs two tools: (i) principle of probability and chances of difference in realised ratio due to smallness of the progeny. (ii) Elimination of alternatives. An **autosomal dominant trait** if present in the pedigree seldom skips a generation (Fig. 5.59 A). An **autosomal recessive trait** may skip a generation (Fig. 5.59 B). It appears in case of marriage between two heterozygous individuals ($Aa \times Aa = 3 Aa + 1 aa$), a recessive individual with hybrid ($Aa \times aa = 2 Aa + 2aa$) and two recessives ($aa \times aa = \text{all } aa$). A **sex-linked dominant trait** is more common in females while a **sex-linked recessive trait** is more common in males. **Y-linked trait** directly passes from father to the son.

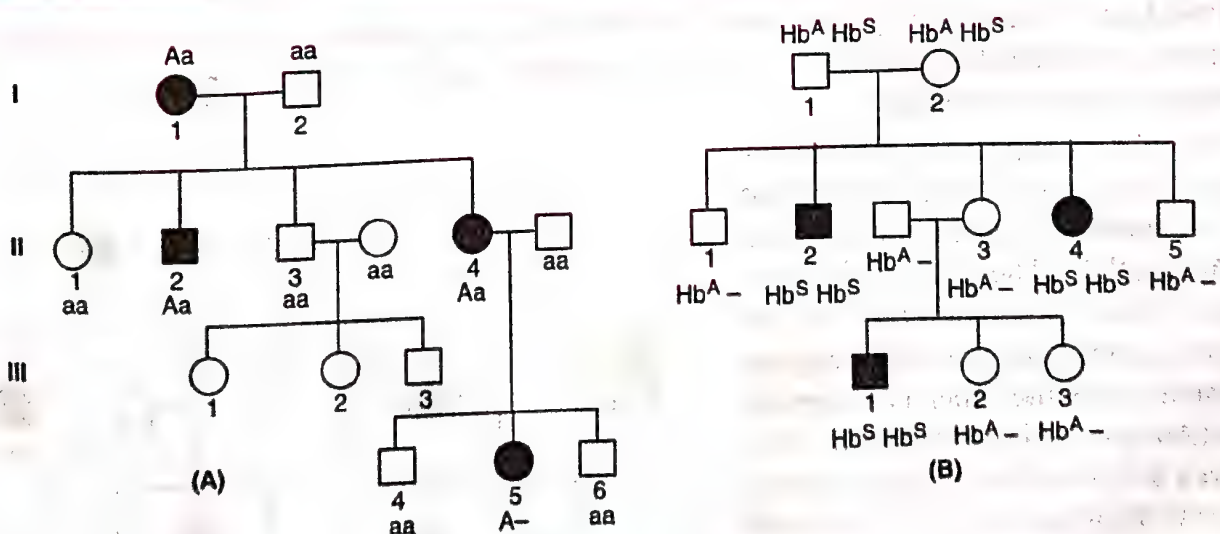


Fig. 5.59. Representative pedigree analysis. A, autosomal dominant traits (e.g., Myotonic dystrophy). B, autosomal recessive trait (e.g., sickle cell anaemia).

A few problems of autosomal inheritance are given below :

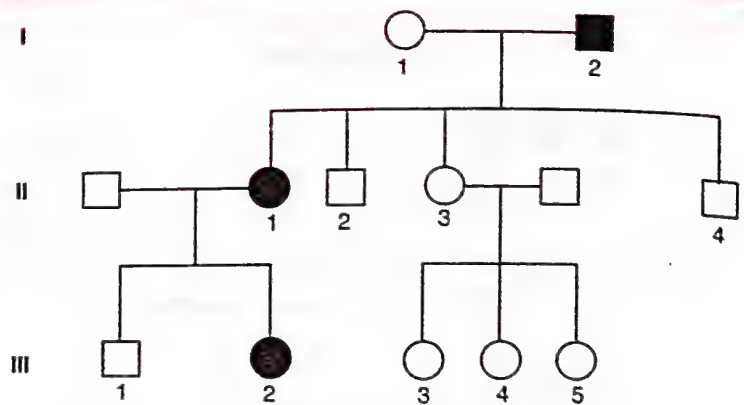
Problem 1. Fused ear lobe appears in the progeny due to a recessive gene. Find out the possible genotypes of the family members in the following pedigree.

The trait is present in the father parent due to presence of two recessive genes (I—2 aa). The trait can appear in the progeny only when it becomes homozygous recessive. Since, only one of the progeny carries the trait, the mother parent must be heterozygous (test cross— $Aa \times aa$ 50% heterozygous, 50% recessive), i.e., I—1 Aa. II—1 is aa. II—2, II—3 and II—4 are heterozygous (test cross) and, therefore, Aa. The cross between II—1 and her husband also produces one homozygous recessive (III—2 = aa). This is possible only if the outsider is heterozygous (Aa). Naturally III—1 is also heterozygous (Aa).

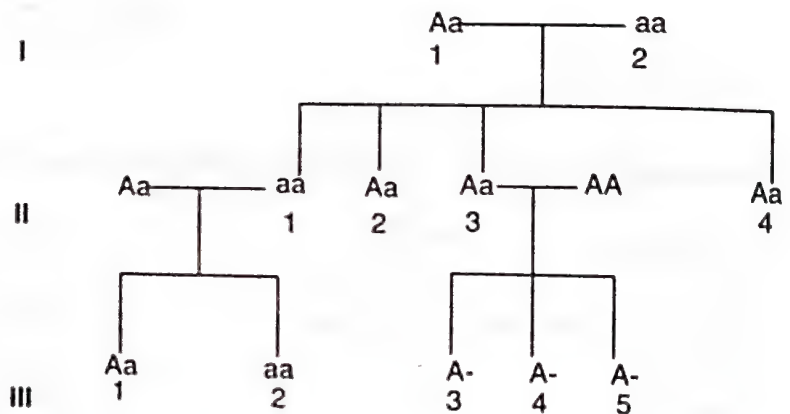
II—3 is heterozygous (Aa). Her husband can be either heterozygous ($Aa \times Aa = AA, 2Aa, aa$) or homozygous dominant ($Aa \times AA = 2AA, 2Aa$). Since none of the progeny is with recessive fused ear lobe, the possibility is that the new entrant in the pedigree is homozygous dominant (AA). III—3, III—4, III—5 are either AA or Aa.

Problem 2. A pedigree given below started with a dark haired lady marrying red haired gentleman. Indicate the genotypes of all the members and whether red hair is due to the dominant or recessive allele.

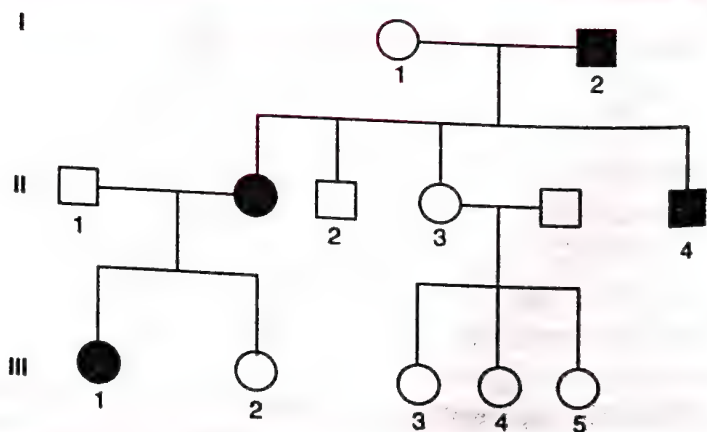
As red hair appears in 50% members of the second generation and not all, it cannot be due to homozygous dominant allele. The same is the condition of dark hair. Therefore, out of the two parents, one is homozygous recessive while the other is heterozygous ($Aa \times aa = 50\% Aa + 50\% aa$). The children are either heterozygous dominant (50%) or homozygous recessive (50%). Only two of the four children marry. One of them is dark haired while the other is red haired. Both marry dark



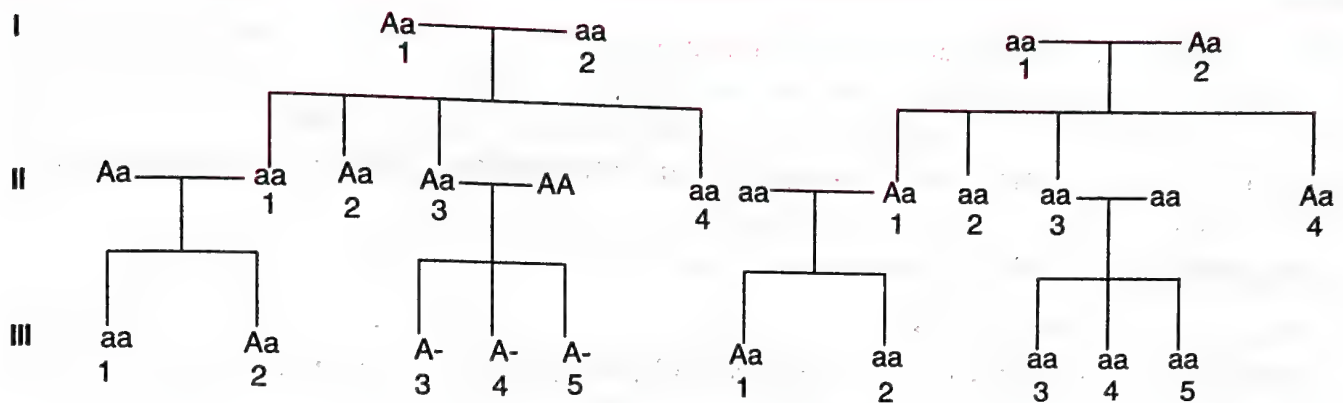
Problem 1. fused ear lobe.



Explanation of above pedigree.



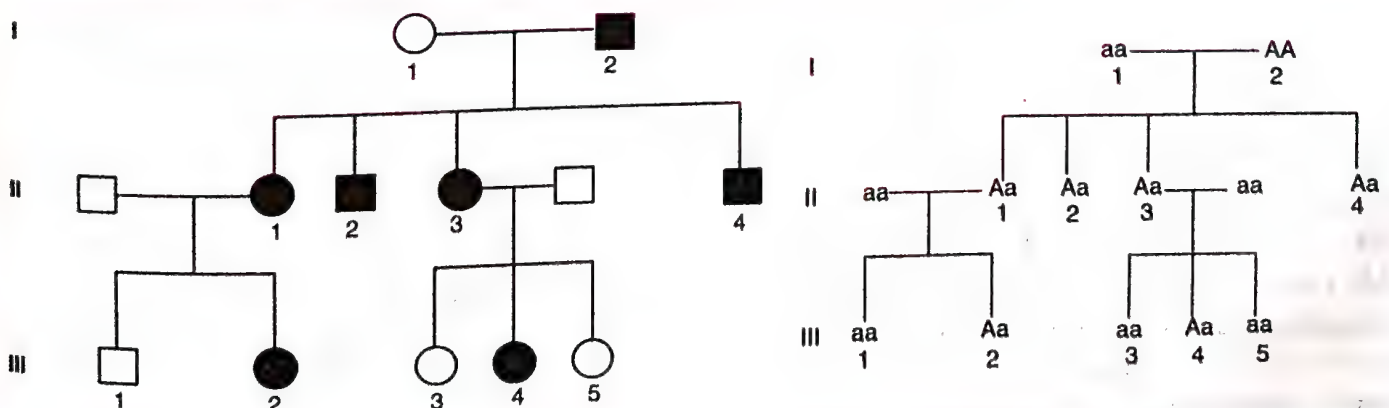
haired partners. The red-dark haired couple produces both red haired and dark haired children while the dark haired one gives rise to dark haired children. The former is possible when one of the two partners is heterozygous dominant while the other is homozygous recessive. The second is possible if dark haired husband is homozygous. In the above pedigree both possibilities of red hair being recessive trait as well as dominant (heterozygous here) are possible. Therefore, the data is insufficient to decide the issue.



Explanation of Pedigree of Problem 2.

Problem 3. In the pedigree given below, indicate whether the shaded symbols belong to dominant or recessive allele. Also give genotype of the whole pedigree.

Since the shaded symbol appears in all the offspring, one of the parents (father) must be homozygous dominant while the mother homozygous recessive ($AA \times aa = \text{all } Aa$) because in all other cases this possibility is absent ($Aa \times aa = 2Aa + 2aa$). All the members of II generation will, therefore, be heterozygous (Aa). This is further confirmed by marriage of II-1 with homozygous recessive ($Aa \times aa = 2Aa, 2aa$) and bearing children of both the parental types. Marriage of II-3 with the homozygous recessive can produce both recessive and heterozygotes as are present here.



HUMAN GENETIC DISORDERS

Human genetic disorders are broadly grouped as follows :

- A. Chromosomal disorders.
- B. Mendelian disorders.

A. Chromosomal Disorders

(Human Genetic Disorders due to Chromosomal Abnormalities)

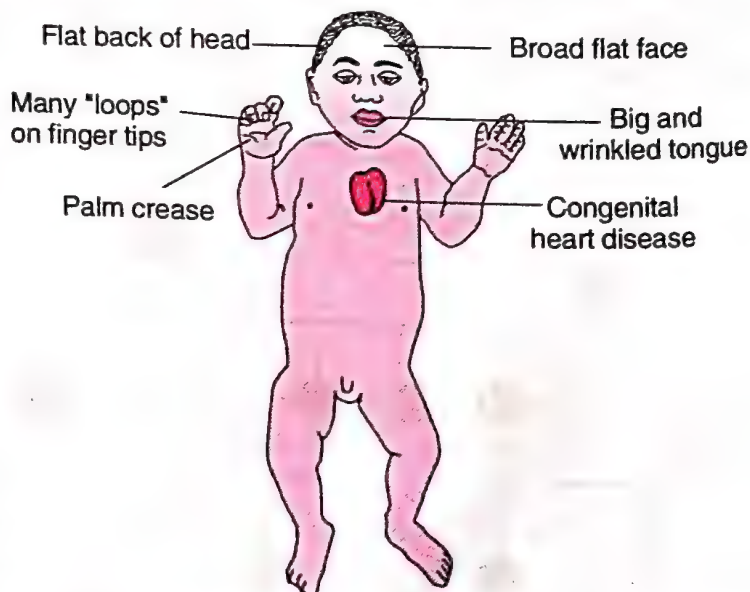
These genetic disorders are caused due to absence or excess or abnormal arrangement of one or more chromosomes. These are **nonheritable** and pedigree analysis of a family does not help in tracing the pattern of inheritance of such chromosomal disorders. These are of two types: abnormalities due to **aneuploidy** and **aberrations** either in autosomes or in sex chromosomes.

Polyploidy condition is often seen in plants.

(a) Autosomal Abnormalities

These are due to autosomal aneuploidy and aberrations. Some of the common genetic disorders of this group are as follows :

1. **Down's Syndrome*** (Mongolian Idiocy, Mongolism, 21-trisomy). The disorder was first reported in 1866 by Langdon Down. It is an autosomal aneuploidy, caused by the presence of an extra chromosome number 21 as shown by Lejeune in 1959. Both the chromosomes of the pair 21 pass into a single egg due to **nondisjunction** during oogenesis. Thus the egg possesses 24 chromosomes instead of 23 and offspring has 47 chromosomes ($45 + XY$ in male, $45 + XX$ in female) instead of 46. Down's syndrome is also called **21-trisomy**. It is characterised by rounded face, broad fore-head, permanently open mouth, protruding tongue, projecting lower lip, short neck, flat hands and stubby (small) fingers, many "**loops**" on finger tips, coarse and straight hair, furrowed tongue, broad palm with characteristic **palmer crease**, which runs all the way across the palm and mongolian type eye lid fold (**epicanthus**). The victim has little intelligence (IQ below 40). Heart and other organs may be defective. Gonads and genitalia are undeveloped. It affects one in 750 babies at birth but over half of fetuses suffering from this syndrome abort spontaneously (miscarriage). The nondisjunction is more in females. The frequency of nondisjunction of chromosome pair 21 increases with mother's age. Among mothers, younger than 25 years old, the risk of having a child with Down syndrome is 1 in 2000; at 30, it is 1 in 900; at 40, 1 in 100 and at 45, 1 in 40. This increased risk in older females is due to factors that adversely affect meiotic chromosome behaviour with advancement of woman age. In



Patient with Down's Syndrome

* Down syndrome, Edward syndrome and Patau syndrome are found in both sexes (M or F).

human females, meiosis starts in the foetus to produce egg cells but it is not completed until after the egg is fertilized. During the long time prior to fertilization, egg cells are arrested in Prophase I. In this suspended state, the chromosomes may become unpaired. The longer the time in Prophase I, the greater the chance for unpairing and chromosome nondisjunction.

Down's syndrome does not run in the families as it is related to abnormal behaviour of chromosomes during meiosis. However, about 3–4% of Down's syndrome cases are due to translocation of chromosome 21 to chromosome 14 or less commonly to chromosome 22 and even less common cause is a 21 to 21 translocation. It is called **familial Down's syndrome**. The number of chromosomes remains 46 but there is a partial trisomy.

2. **Edward's Syndrome (18-Trisomy)**. It was described by Edward in 1960. This syndrome is due to an extra chromosome number 18. Thus total number of chromosomes is 47. It occurs more often in females than in males. The frequency of this abnormality is about 1 per 8000 live births. The affected person keeps the fingers tightly clenched against the palm of the hand. Other symptoms are small jaws, deformed ears, small mouth, nose and after birth.

3. **Patau's Syndrome (13-Trisomy)**. It was described by Patau in 1960. This syndrome is due to an extra chromosome number 13. The affected person has small head and abnormalities of the face, eyes and forebrain, cleft lip and palate, low set deformed ears, small chin and the hands are often clenched in the manner described for Edward's syndrome. It occurs in about 1 in 20,000 live births. The average life span of the affected person is about 4 months.

4. **Cri-du-chat (Cat Cry) Syndrome**. The affected newborn cries like mewling of a cat. It was first described by Lejeune in 1963 in France. Hence it is named *Cri du chat* (Cat Cry). This condition is due to a deletion of half part in the short arm of the chromosome number 5. It is very rare. The affected person has a small head, widely spaced eyes, moon like face, cry like kitten, receding chin and congenital heart disease.

5. **Myelogenous Leukemia**. It is caused by deletion of some portion of long arm of chromosome 22 and its addition to chromosome 9 (**reciprocal translocation**). It is a cancer of white blood cells characterised by increased and unregulated growth of myeloid cells in the bone marrow and accumulation of these cells in the blood. There is excess production of granular leucocytes, and hence called chronic granulocytic leukemia or chronic myeloid leukemia (CML). The deficient 22nd chromosome whose a little segment from long arm is deleted, is called **Philadelphia chromosome**, as it was first reported in the city of Philadelphia in 1959.



Patient with Cri-du-chat Syndrome

(b) Sex Chromosomal Abnormalities

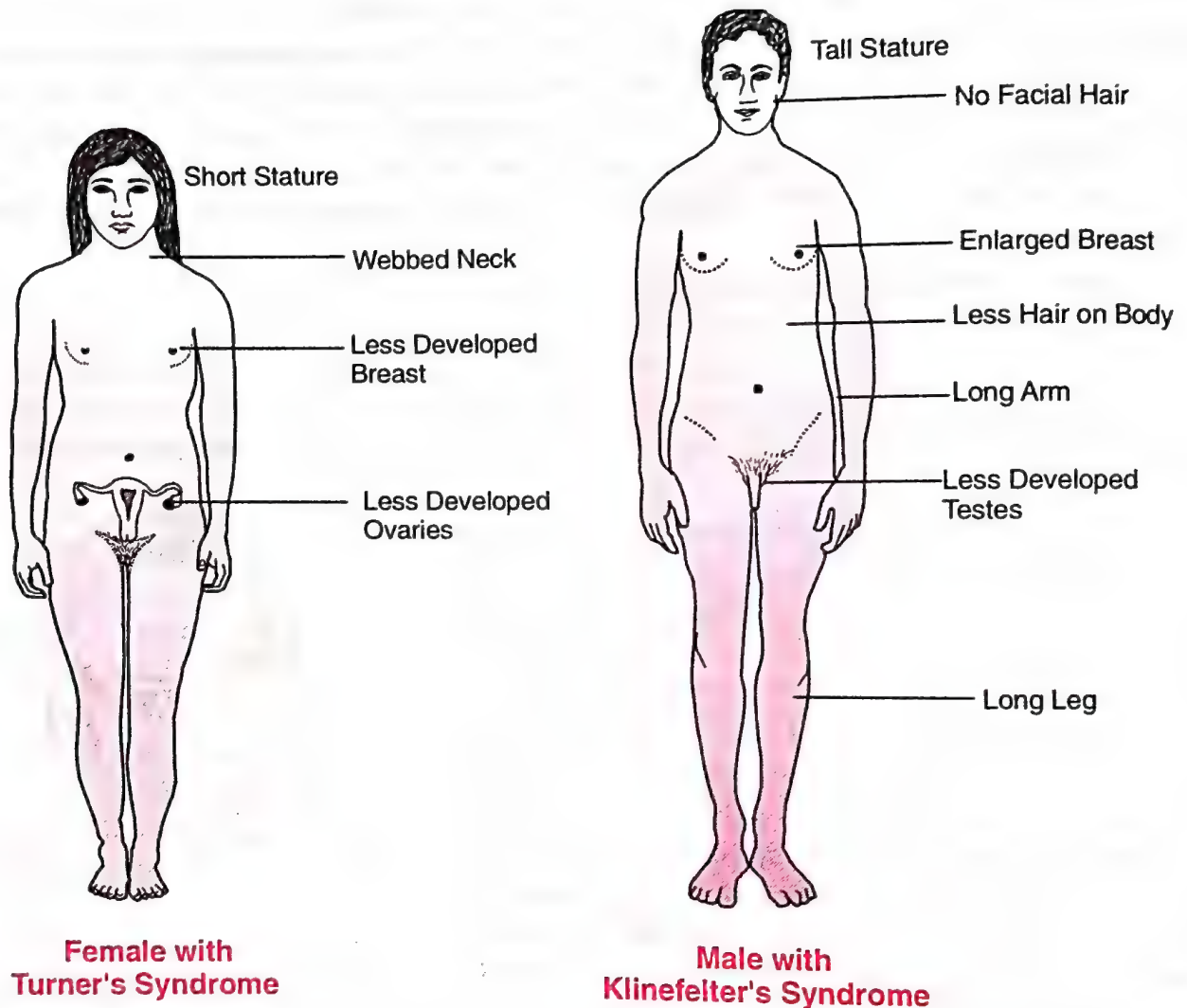
These are due to sex chromosomal aneuploidy and are as follows :

1. **Turner's Syndrome***. Turner's syndrome (Turner, 1938) is due to monosomy

* In Turner's syndrome FSH and estrogen secretion is deficient. This disorder can be treated by giving female sex hormones to women from the age of puberty to make them develop breasts and have menstruation. This makes them feel more normal. It does not cure infertility.

($2n - 1$). It is formed by the union of an allosome free egg ($22+0$) and a normal X sperm or a normal egg and an allosome free sperm ($22+0$). The individual has $2n = 45$ chromosomes ($44 + XO$) instead of 46. Such persons are **sterile females** who have rudimentary ovaries, undeveloped breasts, small uterus, puffy fingers (peripheral lymphoedema), short stature (less than 5 feet), webbed neck and abnormal intelligence, cardiovascular abnormalities and hearing impairment. They may not menstruate or ovulate. One in every 3000 female births is a victim.

$44 + YO$ combination (or male Turner's syndrome) is unviable so that it does not occur in nature.



2. **Klinefelter's Syndrome***. Klinefelter's syndrome (Klinefelter, 1942) is due to trisomy of sex (X) chromosome. It is formed by the union of an abnormal XX egg and a normal Y sperm or normal X egg and abnormal XY sperm. The individual has 47 chromosomes ($44+XXY$). Such persons are **sterile males** (called feminised male) with undeveloped testes, mental retardation, female like sparse body hair, and knock knees, **long limbs** and with some female characteristics such as feminine pitched voice and enlarged breasts (**gynaecomastia**). It is considered that the more the X chromosomes, the greater is the mental defect. One in every 500 male births is victim of this syndrome.

* In Klinefelter's syndrome, level of FSH is higher than usual FSH secretion in males. The androgen level is insufficient. This disorder is diagnosed usually after puberty. These males show one barr body ($44 + XXY$). This disorder can be treated by male hormones by which breasts return to normal size but sterility remains.

Differences between Turner's Syndrome and Klinefelter's Syndrome

Character	Turner's Syndrome	Klinefelter's Syndrome
1. Genotype	44 + XO	44 + XXY
2. Sex	Sterile Female	Sterile Male
3. Sex Characters	Undeveloped ovaries and breasts, small uterus, absence of menstruation, absence of sex chromatin, narrow hips.	Undeveloped testes, sparse body hair, feminine pubic hair, gynecomastia, presence of sex chromatin, feminine pitched voice.
4. Other Characters	Short stature, heavy neck muscles, narrow hips, vascular retardation, cardiovascular abnormalities and hearing impairment.	Long limbs, knock knees, mental retardation.

3 **Superfemales** (Poly X female syndrome). Such individuals have 47 (44 + XXX, triple-X), 48 (44 + XXXX) or 49 (44 + XXXXX) chromosomes. These females are characterised by abnormal sexual development and mental retardation. The number of barr bodies is one less than total number of X chromosomes. The frequency at birth of 44 + XXX is 1 in 1500. The symptoms are more severe with the increase in number of X chromosomes. Such females are taller with commonly normal fertility.

4. **Supermales** (Poly Y male syndrome). Such individuals have 47 (44 + XYY) chromosomes. These males are characterised by abnormal height, mental retardation, antisocial and criminal bent of mind (criminal syndrome or Jacob's syndrome). There is an over-production of male sex hormones. Supermales are more aggressive than normal males. Its frequency is 1 in 1000. Such males are taller with IQ 80–120. They are normal in sexual function, fertility and genitalia.

Summary of Different Number of Sex Chromosomes in Human Beings

Number of Sex Chromosomes	Nature of Abnormality
Females	
1. XO	Turner's syndrome
2. XX	Normal Female
3. XXX	Super female
4. XXXX	— do —
5. XXXXX	— do —
Males	
1. XY	Normal male
2. XYY	Super male
3. XXY	Klinefelter's syndrome
4. XXYY	— do —
5. XXXY	Extreme Klinefelter's syndrome
6. XXXXY	— do —

B. Mendelian Disorders

(Gene Related Human Disorders)

These disorders are determined by mutations in single genes. They are transmitted to the offspring as per Mendelian principles. The pattern of inheritance of such Mendelian disorders can be traced in a family by the **pedigree analysis**. Some common mendelian or gene related human disorders are as follows :

(a) Gene Mutations in Autosomes

These are of two types : **recessive** and **dominant**.

(i) Recessive Traits.

These are caused by recessive autosomal genes when present in homologous condition.

1. **Alkaptonuria***. This was one of the first inborn metabolic diseases described by Garrod in 1908. It is an inherited autosomal, recessive, metabolic disorder produced due to *deficiency of an oxidase enzyme required for breakdown of tyrosine. Its toxic by product homogentisic acid (also called alcapton) accumulates*. The disease is called alkaptonuria (also written as alcaptonuria). Lack of the enzyme is due to the absence of the normal form of gene on chromosome 3 that controls the synthesis of the enzyme. Hence, homogentisic acid accumulates in the tissues and is also excreted in the urine. The most commonly affected tissues are heart valves, cartilages (ochronosis), capsules of joints, ligaments and tendons. The urine of these patients if allowed to stand for some hours in air, turns black due to oxidation of homogentisic acid. AA and Aa are normal but aa is alkaptonuric. The major defects are heart problems, arthritis, kidney and prostate stones. Nitisinone gives relief.

2. **Albinism**. It is an autosomal, recessive genetic disorder. It is caused by the absence of the enzyme **tyrosinase** which is essential for the synthesis of melanin pigment from dihydroxyphenylalanine. The gene for albinism (a) does not produce the enzyme tyrosinase but its normal allele (A) does. Thus, only homozygous recessive individual (aa) is affected by this disease. Albinos (individuals with albinism) lack dark pigment **melanin** in the skin, hair and iris. Although albinos have poor vision yet they lead normal life.

3. **Tay-Sach's** Disease (TSD)/Infantile Amourotic Idiocy**. It is an autosomal, recessive genetic disorder. Homozygous children show degeneration of central nervous system due to accumulation of a fatty substance (sphingolipid) in nerve cells. This is caused by the enzyme β -D-N-acetyl hexosaminidase which in normal individuals exists in two forms A and B. In TSD, only the A form is present, the B form is not present. This disease was first reported by Warren Tay in 1881. Later on, in 1887 Bernard Sach described the first pathological description of the disease. Children with Tay-Sach's disease are born normal but develop severe brain and spinal cord damage later in a few



An Individual with Albinism

*Alkaptonuria, Phenylketonuria and Albinism are defects in Amino Acid Metabolism.

**Tay Sach's disease and Gaucher's disease are defects in Lipid Metabolism.

months due to an error in fat metabolism. The mentally retarded and progressively paralysed child dies in 3 to 4 years. There is no treatment for this disease and, hence, no survivors.

4. Gaucher's Disease. It is an autosomal, recessive genetic disorder. In this disorder the breakdown of fatty acid substance cerebroside is impaired leading to accumulation of lipid materials in body tissues and blood. It is caused by an autosomal recessive gene present on chromosome 1. It inhibits the activity of an enzyme glucocerebrosidase in lysosome. Consequently there is accumulation of cerebroside (a sphingolipid). There is enlargement of the spleen and liver and expansion of some of the limb bones.

5. Sickle Cell Anaemia (Herrick, 1904). Sickle cell anaemia is an autosomal hereditary* disorder in which the erythrocytes become sickle shaped under oxygen deficiency as during strenuous exercise and at high altitudes. The disorder or disease is caused by the formation of an abnormal haemoglobin called haemoglobin-S. As found out by Ingram (1958), haemoglobin-S differs from normal haemoglobin-A in only one amino acid—6th amino acid of β -chain. Here, **glutamic acid** is replaced by **valine** due to substitution (transversion) of T by A in the second position of the triplet codon (CTC) which is changed to CAC. The gene is situated on chromosome 11. The codon CTC is transcribed into GAG (coding for glutamic acid) but due to substitutions of T by A the new codon CAC is transcribed into GUG that codes for valine. This is the major effect of the allele. **Sickle cell crisis** develops under conditions of oxygen deficiency. 6-valine forms hydrophobic bonds with complementary sites of other globin molecules. It distorts their configuration. As a result, erythrocytes having haemoglobin-S become sickle-shaped. This is one of the **secondary effects**. Other secondary effects result from the sickle-shaped erythrocytes. The cells cannot pass through narrow capillaries. They have a tendency to clot and degenerate. It results in **anaemia**. Clogged blood capillaries reduce blood circulation. Tissues are deprived of oxygen. Jaundice can appear. Spleen and brain get damaged. The patient feels acute physical weakness headache and muscle cramps. The homozygotes having only haemoglobin-S usually die before reaching maturity because erythrocyte distortion and degeneration occur even under normal oxygen tension.

Despite having harmful effect, the allele for sickle-cell anaemia continues to persist in human population because it has survival value in malaria infested areas like tropical Africa. Malarial parasite is unable to penetrate the erythrocyte membrane and cause any harm. Further, the sickle cell heterozygotes do not always suffer from syndrome. Their erythrocytes appear normal till there is oxygen deficiency when some sickle-shaped erythrocytes may be observed (Fig. 5.60).

The gene for sickle-celled erythrocytes is represented by Hb^s while that of normal erythrocytes is written as Hb^A . The homozygotes for the two types are $Hb^s Hb^s$ and $Hb^A Hb^A$. The heterozygotes are written as $Hb^A Hb^s$. When two sickle cell heterozygotes marry (Fig. 5.62), they produce three types of children—homozygous normal, heterozygous carrier and homozygous sickle celled in the ratio of 1 : 2 : 1. However, homozygous sickle-celled individuals ($Hb^s Hb^s$) die in childhood (before reproductive age) due to acute anaemia. Therefore, a ratio of one normal to two carriers is obtained.

*Previously sickle cell allele Hb^s was believed to be recessive to normal erythrocyte allele Hb^A . However, in heterozygous individuals both the types of haemoglobin (A and S) are formed. Therefore, the two alleles are now called **codominant**. The allele Hb^s has a frequency of occurrence at birth to be 1 in 1600 among black people; though found in Pakistan and India also.

6. **Thalassemia***. It was discovered by Cooley (1925) but the term was given by Whipple and Bradford (1932) after its prevalence in mediterranean region. The disorder also occurs in middle east, Indian subcontinent and south-east Africa. Thalassemia is autosomal recessive blood disease which appears in children of two unaffected carriers (heterozygous parents). The defect can occur due to mutation or deletion of the genes controlling the formation of globin chains (commonly α and β) of haemoglobin. Imbalanced synthesis of globin chains of haemoglobin causes **anaemia**. Anaemia is the characteristic of the disease. Depending upon the globin chain affected, thalassemia is of three types— α , β and δ .

Alpha Thalassemia. It is caused by the defective formation of α -globin. The latter is controlled by two genes present on chromosome 16, HBA1 and HBA2 with a total of four alleles. Persons with one defective allele are silent carriers while two defective alleles produce **α -thalassemia minor**. Three defective alleles cause accumulation of β -chain tetramers called **haemoglobin Barts** (γ_4) in infants and **haemoglobin H** (β_4) in adults. There is anaemia, jaundice, hepatosplenomegaly and bone changes. All the defective alleles kill the foetus (hydrops foetalis) resulting in still birth or death soon after delivery.

Beta Thalassemia. There is decreased synthesis of β -globin. The defect is due to alleles of HBB gene present on chromosome 11. Persons with one defective allele suffer from **thalassemia minor** with larger number of microcytic erythrocytes and lesser amount of haemoglobin. Persons with both the defective alleles suffer from **Cooley's anaemia** or **thalassemia major**. There is severe haemolytic anaemia, hepatosplenomegaly, cardiac enlargement and skeletal deformities.

Delta Thalassemia. It occurs due to defective allele of HBD gene present on chromosome 11 that forms delta chain of haemoglobin. Adults have about 3% haemoglobin consisting of α and δ chains. Therefore, the effect of this thalassemia is minor.

Thalassemia is a quantitative problem of synthesising too few globin molecules while sickle cell anaemia is a qualitative problem of defective functioning of globin molecules.

7. **Cystic Fibrosis (CF)**. It is an abnormal recessive disorder of infants, children and young adults that is due to a recessive autosomal allele present on chromosome 7. In 70% of cases, it is due to deletion of three bases. It is common in Caucasian northern Europeans and white north Americans. The disease gets its name from the fibrous cysts that appear in the pancreas. It produces a defective glycoprotein. The defective glycoprotein causes formation of thick mucus in skin, lungs, pancreas, liver and other secretory organs. Sweat of the patient contains very high level of Na^+ and Cl^- . There is failure of chloride ion transport mechanism in cell surface membrane of epithelial cell. Accumulation of thick mucus in lungs results in obstruction of airways. Because of it the disease was also called **mucoviscoides**. There is recurrent pulmonary infection and irreversible lung damage. Mucus deposition in pancreas blocks secretion of pancreatic juice. There is maldigestion of food with high fat content in stool. Liver may undergo cirrhosis. There is impaired production of bile. Vasa deferentia of males undergo atrophy. New borns may have obstruction due to thickening of meconium**. **The sweat of the sufferer is saltier**. Child tastes salty from a kiss. The frequency at birth of this disorder is 1 in 1800 among white people and 1 in 100000 births among Africans and Asians. The carriers of this disease have increased resistance to cholera.

8. **Phenylketonuria**. Already discussed under the heading 'Pleiotropy' (Pleiotropic Genes).

*Sickle cell Anaemia and Thalassemias are due to abnormal haemoglobins.

**Meconium — earliest stool of a mammalian infant.

(ii) Dominant Traits.

These are caused by dominant autosomal genes. Some of the dominantly autosomal inherited disorders in human beings are (i) **Achondroplasia**—a form of dwarfism in which long bones do not grow. (ii) **Polydactyly**—presence of extra fingers and toes. (iii) **Brachydactyly**—abnormal short fingers and toes. (iv) A disorder in which the crowns of the teeth are destroyed readily. (v) **Huntington's disease or Huntington's chorea**—a disorder in which muscle and mental deterioration occurs. There is gradual loss of motor control resulting in uncontrollable shaking and dance like movements (chorea). The brain shrinks followed by slurring of speech, loss of memory and hallucinations. This disorder does not occur till the age of 25 to 55. The defective gene is dominant autosomal, located on chromosome 4. The frequency of this disorder is 1 in 10000 to 1 in 20000. (vi) **Phenylthiocarbamide (PTC) tasting**. (vii) Tumor like growths on body (**neurofibromatosis**). (viii) **Wooly hairs**. (ix) **Aniridia** (absence of iris in eye). (x) **Myotonic Dystrophy**—it is characterised by increased muscular irritability and contractibility with decreasing relaxation that leads to atrophy of muscles, especially of face and neck. Other symptoms are frontal balding, hypogonadism and cardiac abnormalities.

Alzheimer's Disease

This neuro-degenerative disease of brain is caused by the accumulation of amyloid protein plaques in the brain resulting in the degeneration of neurons. Choline acetyl transferase activity is impaired. The protein involved, **amyloid- β peptide**, is produced and processed in a number of ways in the brain. This disease is due to ageing and involvement of two defective autosomal alleles, one on the chromosome 21 and other on chromosome 19. This disease is common in Down Syndrome – (21-trisomy). Different genes have been linked to Alzheimer's disease but these genes only predict susceptibility to disease. This disease is characterised by dementia (mental deterioration) leading to loss of memory. A bacteriophage spray has been found to reduce the impact of the disease.

(b) Gene Mutations in Sex Chromosomes

Some genetic disorders are produced by changes (substitution) in the genes lying in the sex chromosomes. These are called **sex linked disorders**. The transmission of sex-linked characters (traits) from parents to offspring is called **sex-linked inheritance**. The following are the sex-linked disorders which are caused by recessive gene located in the X chromosome and affect the males more than the females.

Differences between Chromosomal and Mendelian Disorders	
Chromosomal Disorders	Mendelian Disorders
1. The disorders are caused by chromosomal abnormalities.	1. The disorders are caused by allelic abnormalities.
2. Chromosomal abnormalities develop due to defective synapsis and disjunction.	2. Allelic abnormalities develop due to mutations.
3. The defect can be known through amniocentesis.	3. The defect can be predicted through pedigree analysis.
4. The disorder is rarely transmitted.	4. The disorder is transmitted to the progeny.

1. **Haemophilia** (John Otto, 1803). It is sex-linked disease which is also known as **bleeder's disease** as the patient will continue to bleed even from a minor cut since he or she does not possess the natural phenomenon of blood clotting due to absence of antihemophilic globulin or factor VIII (haemophilia-A) and plasma thromboplastin factor IX (haemophilia-B, Christmas disease) essential for it. As a result of continuous bleeding, the

patient may die of blood loss*. There is no permanent cure of the disease. However, transfusion of normal blood checks bleeding because it provides the vital factors for blood clotting. Antihaemophiliac globulin is also available for use in haemophilia A.

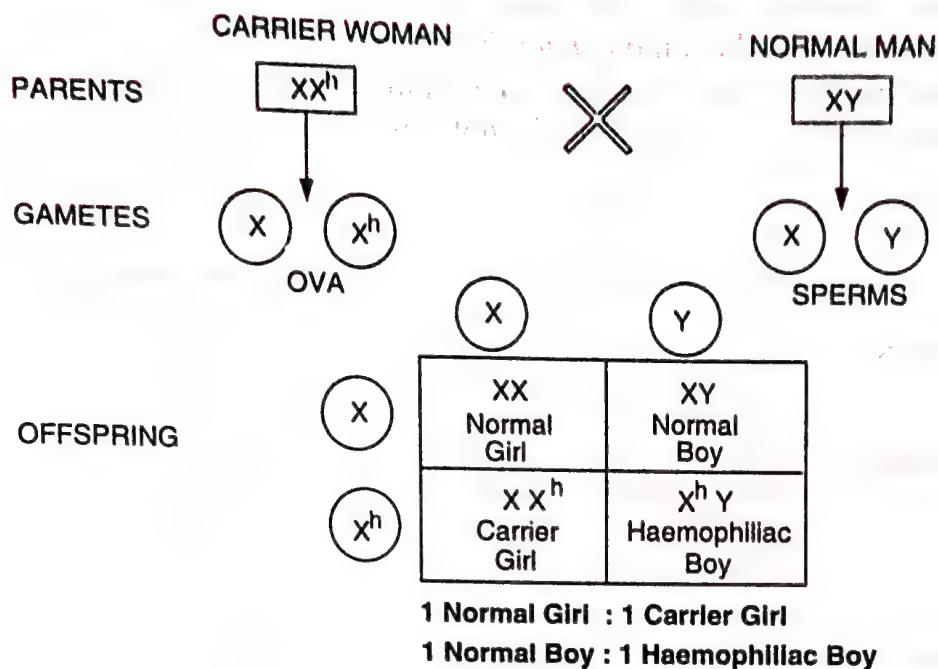


Fig. 5.63. Inheritance of haemophilia by 50% of the male children when the mother is carrier and the father is normal.

Haemophilia (= hemophilia) is genetically due to the presence of a recessive sex linked gene h , carried by X-chromosome. A female becomes haemophiliac only when both its X-chromosomes carry the gene ($X^h X^h$). However, such females generally die before birth because the combination of these two recessive alleles is lethal. A female having only one allele for haemophilia (XX^h) appears normal because the allele for normal blood clotting present on the other X-chromosome is dominant. Such females are known as carriers. In case of males, a single gene for the defect is able to express itself as the Y-chromosome is devoid of any corresponding allele (X^hY). Haemophilia disease (Royal Disease) has been quite common in the royal families of Europe. The disease spread to them through the children of Queen Victoria (1819–1901). The ancestors of the queen did not possess the disease. It appears that the gene for haemophilia developed either in the germ cells of her father or herself through mutation. Being sex-linked, the gene for haemophilia shows criss-cross inheritance. Its frequency is 1 in 7000 in human males and 1 in 10000000 in females.

Haemophiliac (= hemophilic) male baby can be born to a normal couple if the wife is carrier for haemophilia (XX^h). The ova of such a lady shall be of two types, (X) and (X^h). Fusing with the normal sperms of the male, (X) and (Y), the marriage can produce four types of children XX , XX^h , X^hY , XY (Fig. 5.63). In other words, 50% of the boy babies as well as 50% of the girl babies receive the gene for haemophilia through the X^h chromosome of their mother. However, the defect does not appear in the girl babies because of the presence of the allele for normal blood clotting found on the second X-chromosome (XX^h). Therefore, the girl babies remain carrier. 50% of the male babies who receive the defective gene for

*In Haemophilia, blood does not clot within 3–8 minutes. It takes one hour or more.

haemophilia ($X^h Y$) suffer from the disease as their Y-chromosome does not carry any allele for it.

If haemophiliac man marries a normal woman, the disease does not appear in any of the immediate children because 'haemophilia-bearing' X-chromosome of the male is directly transferred to the daughter only. The daughters receive a normal X-chromosome from the mother. Therefore, they become carrier. The sons receive the Y-chromosome from their father (which does not carry the gene for haemophilia) and normal chromosome from their mother. Therefore, in this case the sons do not get the allele for haemophilia (Fig. 5.64).

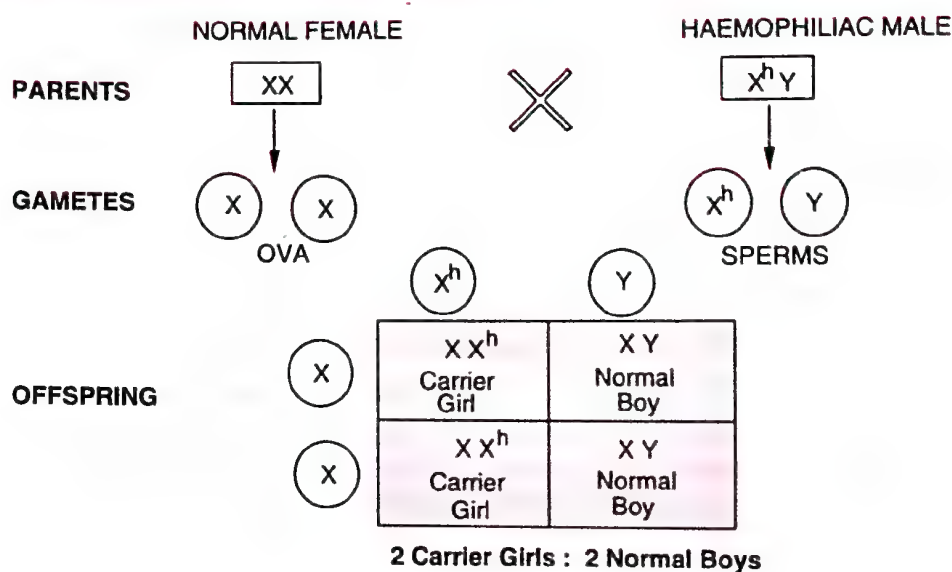


Fig. 5.64. Production of normal children when the father is haemophiliac and the mother is normal. This is because the X-chromosome of the male carrying the defective gene is passed on to the daughter who becomes carrier.

Differences between Haemophilia and Sickle Cell Anaemia	
Haemophilia	Sickle Cell Anaemia
<ol style="list-style-type: none"> 1. It is a sex linked or allosomic disorder. 2. Inheritance is criss-cross. 3. The defective allele influences a single trait. 4. A single allele can produce effect only in males. 	<ol style="list-style-type: none"> 1. It is an autosomal disorder. 2. Inheritance is straight from both the parents to all the offspring. 3. The effect is pleiotropic, one major and a few secondary. 4. A single allele can produce effect in both the sexes but only under conditions of oxygen stress..

A marriage between a carrier woman and haemophiliac man produces 50% normal boy babies and 50% haemophiliac ones. 50% girl babies will be carriers (Fig. 5.70) while the remaining 50% girl babies are haemophiliac. Of course, the haemophiliac girl babies are still born because the double recessive gene of haemophilia is fatal. The surviving girl babies appear normal as they also contain the dominant gene for normal bleeding.

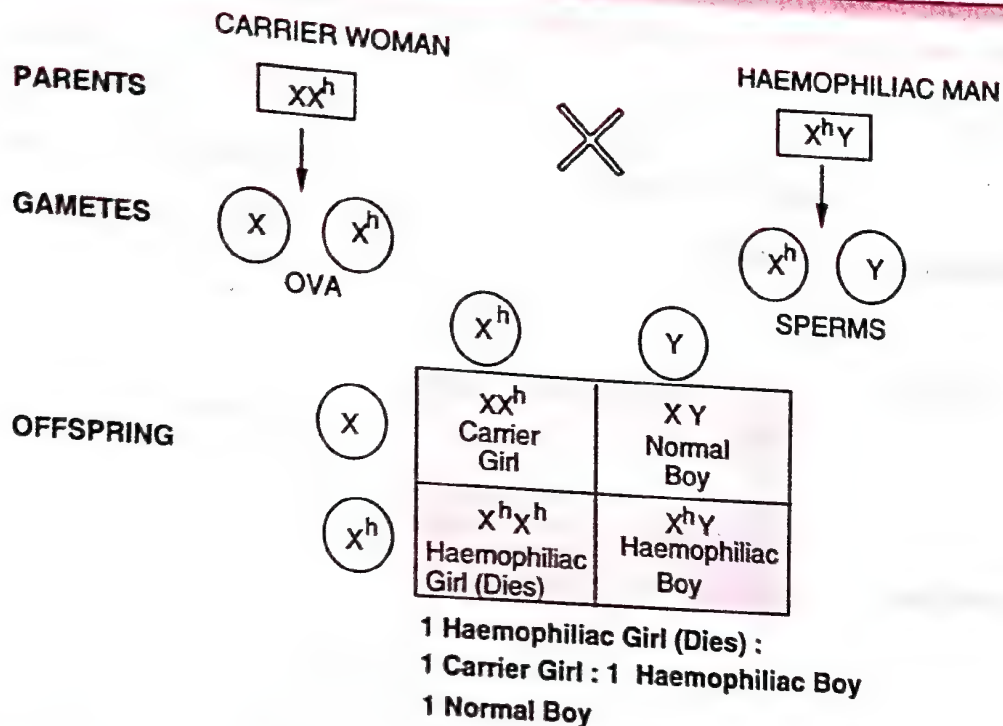


Fig. 5.65. Children of carrier mother and haemophiliac father.

2. Colour Blindness (Red Green Colour Blindness; Horner, 1876). Colour blindness is a recessive sex-linked trait in which the eye fails to distinguish red and green colours. Vision is, however, not affected and the colour blind person can lead a normal life, reading writing and driving (distinguishing traffic lights by their position). The gene for the normal vision is dominant. The normal gene and its recessive allele are carried by X-chromosomes. In females colour blindness appears only when both the sex chromosomes carry the recessive gene ($X^c X^c$). The females have normal vision but function as carrier if a single recessive gene for colour blindness is present (XX^c). However, in human males the defect appears in the presence of a single recessive gene ($X^c Y$) because Y-chromosome of male does not carry any gene for colour vision. As a result colour blindness is more common in males (8%) as compared to females (0.4%). Colour blindness like any other sex-linked trait, shows **criss-cross inheritance**.

50% of the male children shall be colour blind if a carrier woman marries a normal man. 50% of the female children shall also carry the recessive allele for colour blindness but they have normal vision because the dominant allele for normal vision is also present in them. In this particular cross, both the types of sperms, androsperms (Y) and gynosperms (X) are free from the trait of colour blindness. However, the carrier woman produces two types of eggs, without (X) and with the trait (X^c). Fusion of the latter with androsperms produces colour blind boys while fusion with gynosperms forms carrier girls (Fig. 5.66).

The progeny of a colour blind woman ($X^c X^c$) and a normal man (XY) shall consist of 100% colour blind boys and 100% carrier girls. This is because all the eggs of the female shall carry the trait of colour blindness. Both the types of sperms (androsperms and gynosperms) are free from the trait. However, all the male babies will become colour blind as they obtain the allele for colour blindness from their mother. Their Y-chromosome does not possess any gene for colour vision. Therefore, the single recessive allele got from the mother finds

expression in them. However, in case of girl babies the dominant allele for normal vision is present. It does not allow the recessive allele to express itself (Fig. 5.67).

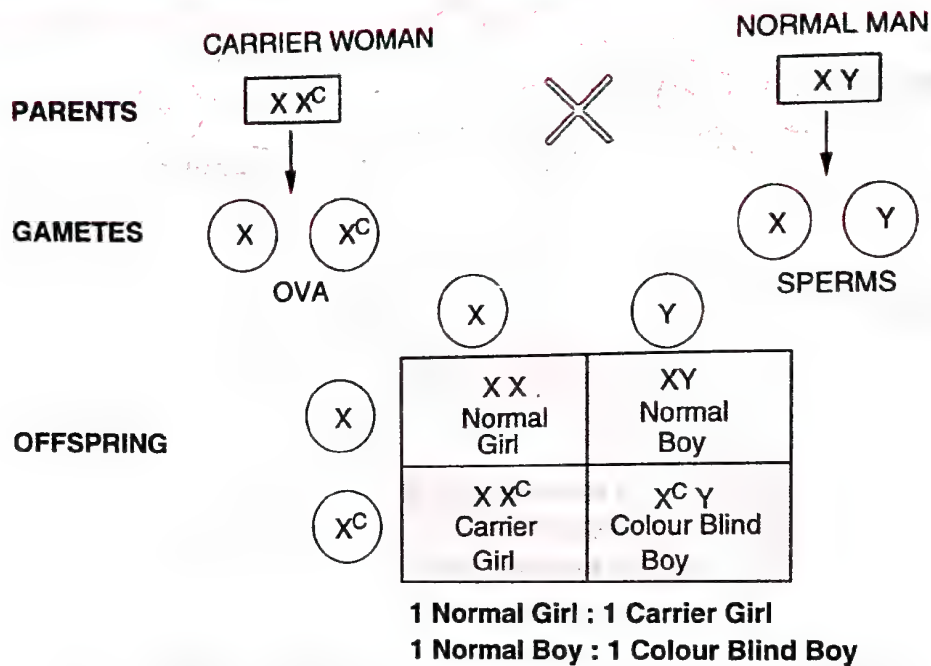


Fig. 5.66. Progeny of carrier woman for colour blindness and a man with normal vision.

Daltonism. The famous physicist John Dalton was colour blind and he gave the earliest account of this condition.

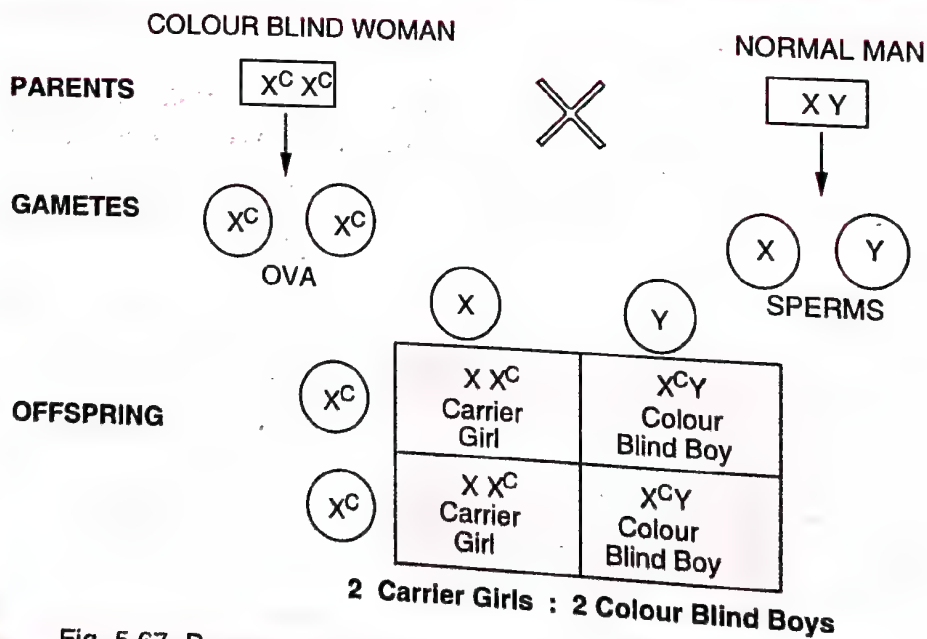


Fig. 5.67. Progeny of a colour blind woman and a man with normal vision.

All the children of a colour blind woman ($X^c X^c$) and a colour blind man ($X^c Y$) shall be colour blind (Fig. 5.68).

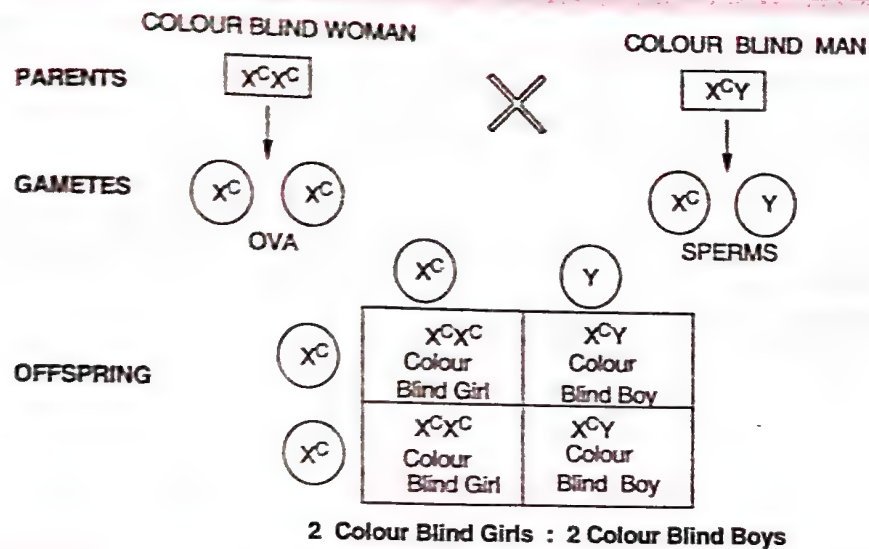


Fig. 5.68. Progeny of a colour blind woman and a colour blind man.

When a normal woman marries a colour blind man all the boy babies are normal. All the girl babies are carrier, of course, with normal vision because the allele for the latter is dominant over the allele for colour blindness. The girl babies receive the recessive trait of colour blindness from X^c -chromosome of their father (Fig. 5.69).

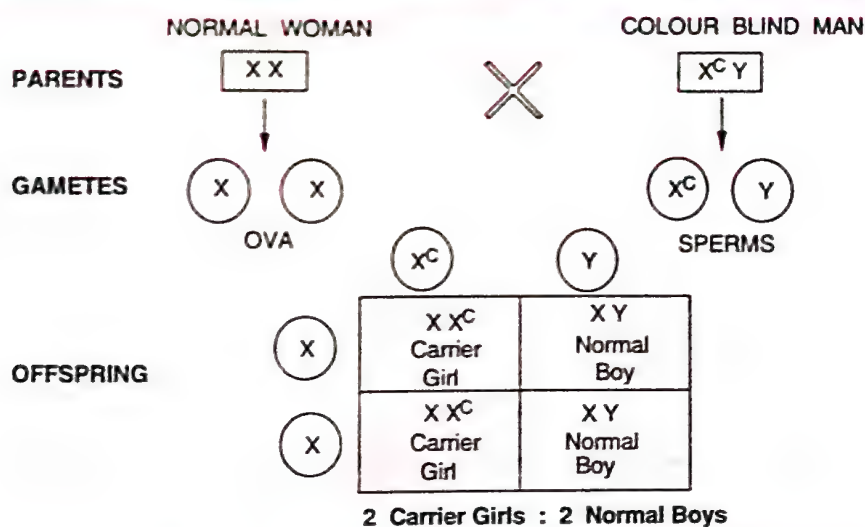


Fig. 5.69. Progeny of a normal woman and a colour blind man.

3. **Night Blindness.** It is caused by a recessive gene carried by X chromosome. The genetic disorder is also more common in males. Actually, night blindness is of two types: (i) **Acquired.** Due to **vitamin A deficiency**; (ii) **Congenital.** Due to visual purple deficiency that interferes with the functions of the retinal rods. It is inherited like red green colour blindness. Females become night blind only if they receive two genes for defect.

4. **Duchenne's Muscular Dystrophy (DMD).** In this disorder the mutated gene (this is largest gene with 2400 kbp in man) present in the middle of the short arm of the X chromosome is unable to produce a protein called **dystrophin** in the skeletal muscles. The latter is believed to relay the nerve's signal to the calcium storage in the muscle cell. This protein is associated with the sarcolemma (plasma membrane of muscle) where it plays a role in transmembrane signalling and in stabilizing the plasma membrane. Due to its deficiency, calcium is not released from the muscle cell. As a result the muscle contraction does

not take place. Abnormal rise of calcium levels in the muscle releases an enzyme that destroys actin and myosin resulting in fatal muscular weakness. There is *deterioration of girdle muscles at an early age*. The patient is unable to walk after the age of 12 followed by cardiomyopathy, mental impairment and death by the age of 20 due to cardiac or respiratory failure. It is common in males. Female heterozygous carriers are normal.

Some Human Autosomal and Sex linked Genetic Disorders

Disorder	Dominant/ Recessive	Autosomal/ Sex linked	Symptom	Effect
Sickle-cell anaemia	Recessive	Autosomal, gene on Chromosome 11	Aggregation of erythrocytes, more rapid destruction of erythrocytes leading to anaemia.	Abnormal haemoglobin in RBC's
Phenylketonuria	Recessive	Autosomal, gene on Chromosome 12	Failure of brain to develop in infancy, mental retardation, idiots	Defective form of enzyme phenylalanine hydroxylase.
Cystic fibrosis (CF)	Recessive	Autosomal, gene on Chromosome 7	Excessive thick mucus clogging in lungs, liver and pancreas anomalies.	Failure of chloride ion transport mechanism through cell membrane.
Huntington's disease (HD)	Dominant	Autosomal, gene on Chromosome 4	Gradual degeneration of brain tissue in middle age, loss of motor control.	Production of an inhibitor of brain cell metabolism.
Haemophilia A/B	Recessive	Sex-linked, gene on X chromosome	Failure of blood to clot	Defective form of blood clotting factor VIII/IX.
Colour blindness	Recessive	Sex-linked, gene on X chromosome	Failure to discriminate between red and green colour.	Defect in either red or / and green cone cells of retina.
Down's Syndrome		Autosomal, Aneuploidy (Trisomy, +21)	Mongolian eyefold (epicanthus), open mouth, protruded tongue, projected lower lip, many loops on finger tips, palm crease	Retarded mental development IQ below 40
Turner's Syndrome		Sex chromosomal Monosomy 44 + X0	Short stature females (<5'), webbed neck, body hair absent, menstrual cycle absent, sparse pubic hair, underdeveloped breasts	Sterile, hearing problem
Klinefelter's syndrome		Sex chromosomal Aneuploidy (Tri/tetrasomy of X chr) 44 + XXY, 44 + XXXY	narrow lips, puffy fingers. These males are tall with long legs, testes small, sparse body hair, barr body present, breast enlargement.	Gynaecomastia, azospermia, sterile

Differences between Autosomal and Sex Chromosomal Disorders

<i>Autosomal Disorders</i>	<i>Sex chromosomal Disorders</i>
<ol style="list-style-type: none"> 1. These arise by gene mutations in autosomal chromosomes. 2. These disorders affect both the sexes, i.e., males and females. 3. The mutated gene may be dominant/recessive. 4. The sufferer is homozygous or heterozygous. <p>Examples. Down's syndrome, Huntington's chorea, sickle cell anaemia, alkaptonuria.</p>	<ol style="list-style-type: none"> 1. These arise in sex chromosomes (allosomes) (mostly X chromosome) 2. These disorders affect the males more than the females. 3. The mutated gene is recessive. 4. The sufferer is hemizygous. <p>Examples. Klinefelter's syndrome, super female, Turner's syndrome, haemophilia, muscular dystrophy.</p>

Differences between Autosomal Characters and Sex Linked Characters

<i>Autosomal Characters</i>	<i>Sex Linked Characters</i>
<ol style="list-style-type: none"> 1. There are two alleles for an autosomal character in all individuals. 2. These characters are equally distributed in both males and females. 3. R-cross (reciprocal cross) in these characters gave the same result. 4. Recessive allele expresses only in homozygous form in both males/ females. 	<ol style="list-style-type: none"> 1. The males carry only one while the females have two alleles of such characters. 2. These X-linked characters show criss cross inheritance while Y-linked genes are inherited from father to son only. 3. R-cross gives different results. 4. Recessive allele present on X chromosome expresses singly in male and in homozygous form in females.

IMPORTANCE OF MENDELISM/GENETICS

1. **Inheritance of Characters.** It tells us about the mechanism of inheritance of characters.

2. **Variations.** It provides information as to the origin of variations. Artificial induction of variations has become an important method of obtaining desired traits.

3. **Improvement of Plants.** With the help of selective hybridisation, back crosses and self breeding, scientists have been able to produce new varieties of plants for higher yield, better quality, disease resistance and prevention of lodging. Successful production of high yielding crop varieties resulted in **green revolution**.

4. **Improvement of Animals.** Successful breeding of high yielding and disease resistant varieties have resulted in increase in milk yield (**white revolution**), egg yield (**silver revolution**) and fish yield (**blue revolution**).

5. **Improvement in Human Race.** Human race can be improved through properly following the principles of heredity. This special branch of study is called **eugenics**. Being a highly heterozygous population, human beings should avoid marriages between close relations as recessive harmful traits can appear due to inbreeding. Genetic defects also appear more commonly in infants of very young and very old couples. The same should be avoided.

6. **Genetic Counselling.** It is useful in avoiding appearance of harmful genes and hereditary diseases amongst susceptible couples.

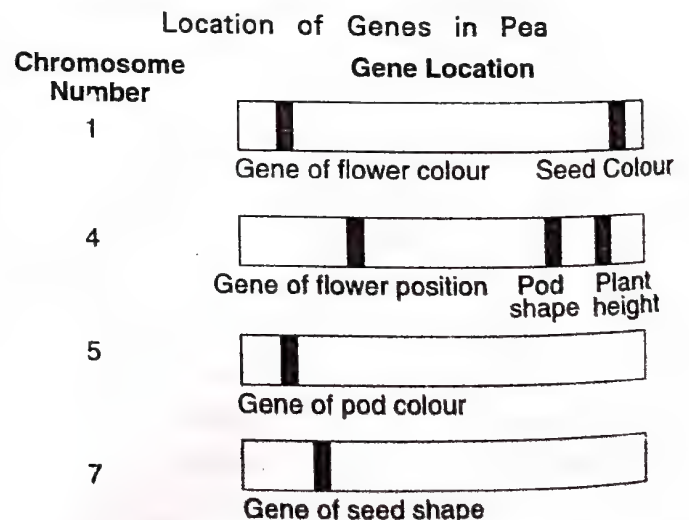
7. **Disputes of Legitimacy.** Disputes of legitimacy or parentage can be resolved through study of genetic traits like blood groups. DNA fingerprinting is the latest contribution of the science of genetics in finding out relationships.

8. **Evolution.** A number of wrong ideas about the process of evolution have been removed by the study of heredity.

9. **Cultural Impact.** No body is now surprised if a child does not have much resemblance with one's immediate parents. The child can have traits of remote fore fathers.

ADDITIONAL INFORMATION

- **Blakeslee (1937).** Discovered the effect of colchicine on induction of polyploidy.
- **Winkler (1916).** Discovered aneuploidy.
- **Haemophilia C.** Autosomal haemophilia caused by deficiency of blood clotting factor XI. It occurs in 1% of the haemophilia cases.
- **Daltonism.** Alternate name of red-green colour blindness after the famous scientist who was afflicted with it.
- **Protanopia.** Red blindness.
- **Deuteronopia.** Green blindness.
- **Ishihara Cards.** Cards used for checking colour blindness.
- **Sex-Linked Inheritance.** (i) Ladies cannot be afflicted with haemophilia (haemophiliac girl babies die in the foetus). (ii) Gents cannot be carrier. (iii) Colour blind women will have colour blind father and colour blind sons. They will have colour blind daughters only when their husbands are also colour blind.
- **Gonochorism.** Sex determination, dioecism.
- **Artificial or Man-Made Allopolyploids.** (i) *Raphanobrassica* between *Raphanus sativum* and *Brassica oleracea* by Karpenchenko (1927). (ii) *Triticale* (= *Tritisecale*) *octaploides* between *Triticum aestivum* and *Secale cereale* by Muntzing (1966).
- **Y-Spot.** Discovered by Zech (1970).
- **Diplotene Chromosomes.** Lampbrush chromosomes.
- **Pseudodominance.** Phenotypic expression of a recessive allele when the dominant allele has been lost due to deletion.
- **Bar Eye.** Presence of an extra B-gene on X-chromosome of fruitfly *Drosophila* results in formation of narrow and smaller eye called bar-eye. While the normal eye has 780 facets, a bar eye has 200-358 facets.
- **ets.** The abnormality is due to duplication of gene.
- **Gynander.** Individual with patches of other sex.
- **Phage.** A virus that infects bacteria.
- **Taste Blindness of PTC.** It is a genetic dominant trait, discovered by Fox (1932). PTC (Phenylthiocarbamide) has sour taste. About 30% people lack the ability to taste PTC. Genotype TT and Tt are taster of PTC. tt are nontasters (taste blind persons).
- **Dysgenics.** Study of undesirable traits of human race and the genes that cause them.
- **Characters Chosen by Mendel.** The genes for seven characters chosen by Mendel are present on four chromosomes. (Blixt 1961)
 - (i) **Chromosome 1** — Flower colour and seed colour.
 - (ii) **Chromosome 4** — Flower position, pod shape and plant height.
 - (iii) **Chromosome 5** — Pod colour.
 - (iv) **Chromosome 7** — seed shape.



- **Coupling and Repulsion Hypothesis** (Bateson and Punnett). In the **coupling** or **cis-phase**, the alleles of a parent tend to remain together. In **repulsion** or **trans-**

phase, as found in F_1 hybrids, the alleles tend to separate.

- **Males Die Early.** X-chromosome is a large chromosome with some 2000 genes. All the recessive alleles present on it are expressed in males as they are hemizygous. The harmful effect of these genes tells upon the health of the males who, therefore, die early.
- **Isoalleles.** Alleles producing similar phenotypes but distinguishable amongst themselves through changed optima, e.g., I^{A1} , I^{A2} , I^{A3} .
- **Pseudoalleles.** Genes lying side by side, producing related phenotypic effect and distinguishable through a rare crossing over, e.g., star (dominant) and asteroid (recessive) traits in *Drosophila*.
- **Suppressor or Inhibitor Gene.** A nonlethal gene which inhibits the effect of a nonallelic dominant gene without producing its own effect (c.f., epistatic gene), so that recessive trait becomes common in phenotype. I-gene is inhibitor of purple colour gene (P) in Rice. I-P- combination produces green leaves in Rice like iipp.
- **Duplicate Genes.** Independent genes producing the same or similar effect e.g., B_1b_1 , B_2b_2 for black-white grain colour in Oat. F_2 dihybrid ratio is 15 : 1.
- **Polymeric or Additive Genes.** They are duplicate genes with additive effect so that a new phenotype is formed when they are present together in dominant state. In Summer Squash (*Cucurbita pepo*) S_1 — s_2s_2 and s_1s_1 S_2 — produce spherical fruits independently, disc-shaped fruits (additive effect when present together (S_1 — S_2 —) and cylindrical fruits in the double recessive state ($s_1s_1s_2s_2$). F_2 dihybrid ratio is 9 discoid : 6 spherical : 1 cylindrical.
- **Morphan's Syndrome.** Caused in human beings by a pleiotropic gene which is characterised by slender body, limb elongation, hypermobility in joints, lens dislocation and tendency to develop heart diseases.
- **Bernstein (1924, 1925).** Discovered multiple alleles, codominance and dominant-recessive relationships in determination of human blood groups.
- T. H. Morgan was awarded Nobel Prize in 1933 on the "Role of Chromosomes in Heredity."
- **Kolreuter (1760).** Discovered inheritance to be due to particulate factors. Father of polygenic inheritance.
- **Galton (1883).** Coined the term eugenics.
- **Correns.** Co-rediscovers principles of heredity, gave the name of laws to two of the observations of Mendel, discovered incomplete dominance in 1903 and cytoplasmic inheritance in 1909.
- Hermann Joseph Muller got Nobel Prize in 1946 for "Production of mutations by X-ray irradiations."
- **Shull (1914).** Coined the term heterosis.
- **Meiocyte.** Any cell that undergoes meiosis.
- **Complete Penetrance.** 100% ability of an allelic combination to produce expected phenotype.
- **Incomplete Penetrance.** It is failure of an allelic combination to provide cent per cent phenotypic expression, e.g., polydactyly, diabetes mellitus.
- **Self Sterility.** Found in plants having multiple alleles for compatibility-incompatibility reaction— $S_1, S_2, S_3, S_4, S_5, S_6$, etc. A plant carries two such alleles, e.g., S_1S_2 , S_2S_3 , S_1S_3 , S_2S_4 , S_3S_5 . A pollen grain carries only one allele. If it happens to be one of the two alleles of pistil, the pollen grain fails to form pollen tube.
- **Neurospora as Genetic Material.** *Neurospora crassa* (Pink Bread Mould) became an important experimental material for genetical studies with the discovery of nutritional mutants by Beadle and Tatum (1948) who profounded the famous **one-gene-one enzyme hypothesis**.
- **Gynandromorph** is an individual with parts or patches of both female and male sexes. The phenomenon is called **gynandromorphism**. It was discovered by Morgan and Bridges (1916) in *Drosophila*. It is also found in Silkworm and bees. Gynandromorphs differ from both intersex and hermaphrodites. Intersex is a blend of male and female features while hermaphrodites have both male and female sex organs.
- **Karyotype of Normal Human Being.** Karyotype is the systematized representation of the chromosome complement of a cell or organism depicting the characteristics (number, size, type, form and position of cen-

tromere) of the chromosomes as seen in the metaphase of mitosis.

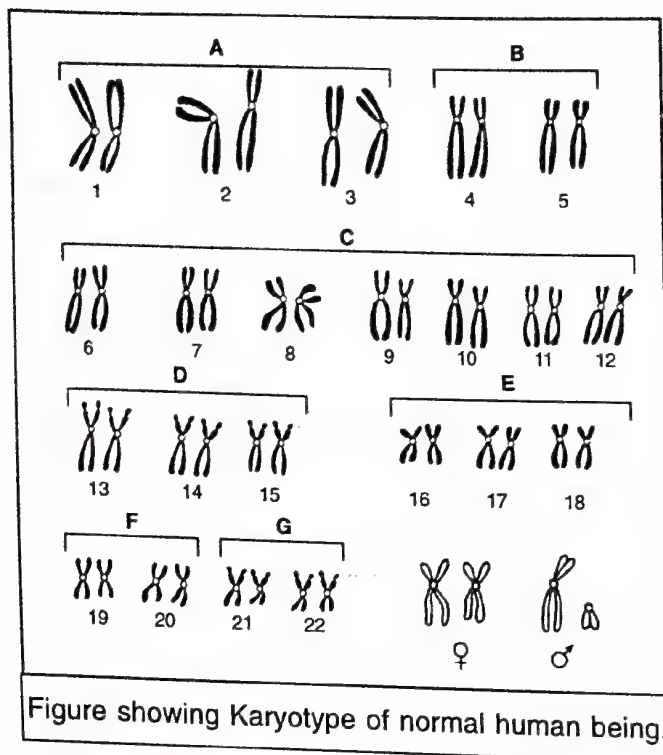


Figure showing Karyotype of normal human being.

The normal diploid ($2N$) chromosome number in human beings is 46. For many years this number was thought to be 48. T. H. Tjio and A. Levan corrected this error in 1956. Each cell of our body contains 23 pairs of chromosomes. These include 22 pairs of **autosomes** and one pair of **sex chromosomes**. The autosomes are similar in males and females. The sex chromosomes are homomorphic (similar) in the female and are known as XX. The sex chromosomes are heteromorphic (dissimilar) in the male and are called XY. The Y chromosome is much smaller than the X chromosome. Thus, a normal human female has 22 pairs of autosomes and an XX pair of sex chromosomes; and a normal human male has 22 pairs of autosomes and an XY pair of sex chromosomes.

Autosomes are grouped in 7 groups namely A, B, C, D, E, F and G as shown in the figure.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

- Mention the advantages of selecting Pea plant for experiment by Mendel.
✓ Mendel selected pea plant because of the following special features : (i) Garden peas were found to differ in certain definite and easily detectable traits. (ii) The plant had bisexual flowers and normally resorted to self pollination. (iii) Artificial cross-pollination could be easily achieved. (iv) Pea plants had a short life cycle. (v) Pea plants produced many seeds in one generation. (vi) Pea plants having each of the seven characters he selected were readily available.
- Differentiate between the following :
(a) Dominance and recessive.
(b) Homozygous and heterozygous.
(c) Monohybrid and dihybrid.
✓ (a) Refer to Important Terms (Dominant Factor and Recessive Factor).
(b) Refer to Important Terms (Homozygous Individual and Heterozygous Individual).
(c) **Differences between Monohybrid and Dihybrid**

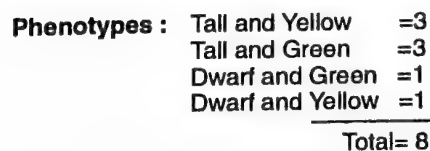
Monohybrid	Dihybrid
(i) It is a cross made between individuals having contrasting traits in order to study the inheritance of a pair of alleles.	(i) It is a cross made between individuals having contrasting traits in order to study inheritance of two pairs of alleles.
(ii) Phenotypic monohybrid ratio in F_2 generation is 3 : 1.	(ii) Phenotypic dihybrid ratio is 9 : 3 : 3 : 1.
(iii) Genotypic monohybrid ratio in F_2 generation is 1 : 2 : 1.	(iii) Genotypic monohybrid ratio in F_2 is 1 : 2 : 2 : 4 : 2 : 2 : 1 : 1 : 1.

- A diploid organism is heterozygous for 4 loci; how many types of gametes can be produced ?
✓ It can be calculated by 2^n . Here n = Number of loci
i.e., $2^4 = 2 \times 2 \times 2 \times 2 = 16$ types of gametes.
- Explain the law of dominance using a monohybrid cross.
✓ Refer to explanation of Law of dominance and figure 5.12.

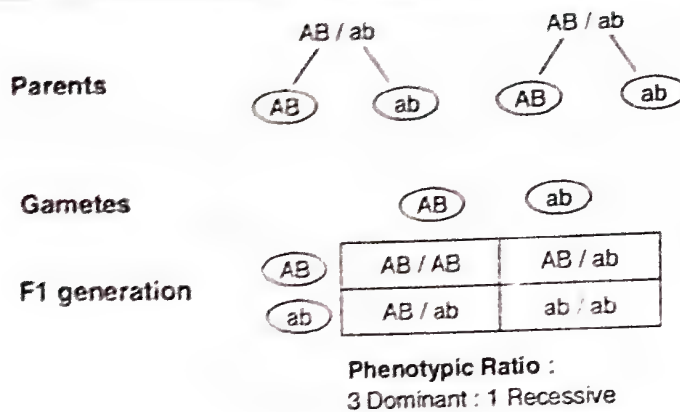
-



- 



- ✓ There will be reshuffling of chromosomes but no reshuffling of genes. Phenotypically dominants and recessives appear in the ratio of 3 : 1.



9. Briefly mention the contribution of T.H. Morgan in genetics.

✓ T.H. Morgan (1866-1945) was an American geneticist who was awarded Nobel Prize in 1933 for his work.

(i) Morgan found fruit fly *Drosophila melanogaster* to be better material for experiments on genetics as it was easy to rear and multiply it throughout the year. (ii) He established the presence of genes over the chromosomes. (iii) Morgan established the principle of linkage and crossing over. (iv) He discovered sex linkage and criss-cross inheritance. (v) He developed the technique of chromosome mapping. (vi) He observed mutations. (vii) In 1926, Morgan wrote a book "The theory of Gene."

10. What is Pedigree Analysis ? Suggest how such analysis can be useful.

✓ **Definition.** It is a method to study the inheritance of a particular trait through many generations by analysing family record.

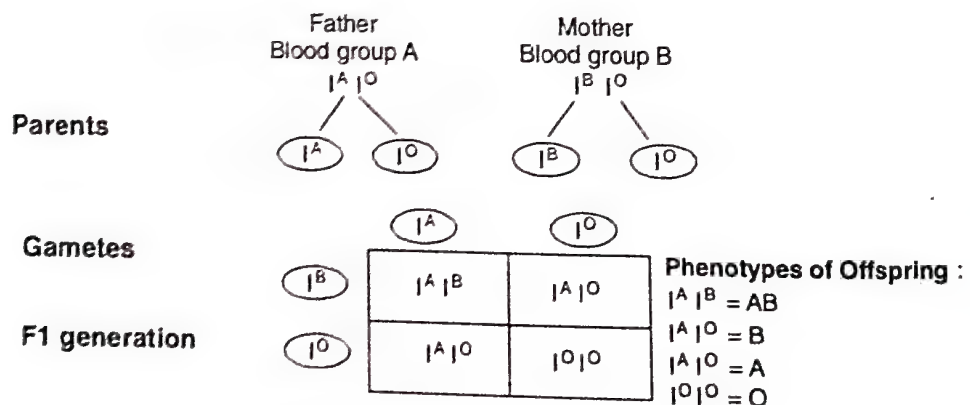
Importance. Pedigree analysis is helpful in finding whether a particular trait is inherited or not. The inheritance of many human traits like haemophilia, colour-blindness, skin colour, polydactyly, etc. is studied by pedigree analysis.

11. How is sex determined in human beings ?

✓ Refer to text (Sex determination in Humans).

12. A child has blood group O. If the father has blood group A and mother has blood group B, work out the genotypes of parent and the possible genotypes of other offspring.

✓ Blood group O is a recessive trait which can appear only when two recessive alleles come together, $I^O I^O$ or ii , therefore, a child can have blood group O only when each parent contributes an I^O allele. For this the father with blood group A must be heterozygous, $I^A I^O$ while the mother should be heterozygous B, $I^B I^O$. Genotype of the offspring (also other than O) can be known from the following checker board.



The child has blood group O

Other offspring can have A, B or AB blood groups.

13. Explain the following terms with example

(a) Co-dominance ; (b) Incomplete dominance.

✓ (a) Refer to text (co-dominance)

(b) Refer to text (incomplete dominance).

14. What is point mutation? Give one example.
✓ The change in single base pair of DNA is called point mutation. The disease sickle cell anaemia is an example of point mutation.
15. Who proposed the chromosomal theory of inheritance?
✓ Sutton and Boveri in 1902 proposed the chromosomal theory of inheritance.
16. Mention any two autosomal genetic disorders with their symptoms.
✓ (a) **Down's Syndrome**. It is due to trisomy of 21st chromosomes. The abnormal children are mentally retarded, have widely placed eyes and open mouth with tongue out.
(b) **Phenylketonuria**. It is a type of autosomal gene mutation caused due to lack of enzyme phenylalanine hydroxylase. This enzyme converts amino acid phenylalanine into tyrosine. The main symptoms of this genetic disorder are (i) Extreme mental retardation. (ii) Hypopigmentation of skin and eczema.

TEXT QUESTIONS

One Mark Questions (With Answers)

1. What are ramets?
✓ The individuals which are carbon copies of one another and/or the parent are called **ramets**.
2. What is a clone?
✓ Group of genetically identical individuals.
3. How cloning can prove useful to plant breeders?
✓ It preserves the genotype.
4. Name the scientists who rediscovered Mendel's principles of inheritance?
✓ Hugo de Vries of Holland, Carl Correns of Germany and Erich von Tschermak of Austria.
5. Who gave the status of laws to Mendel's observations?
✓ Correns
6. Define gene pool?
✓ The aggregate of all the genes and their alleles present in an interbreeding population is known as gene pool.
7. How allele is different from allelomorph?
✓ Both are synonyms.
8. Which one of the following diseases could be avoided in the progeny by analysing the pedigree of the parents— Down's syndrome, Phenylketonuria, Poliomyelitis?
✓ Phenylketonuria.
9. The diploid chromosome number of garden pea is 14. How many linkage groups does this represent?
✓ 7
10. What are autosomes?
✓ Which control most of the morphophysiological characters other than sex.
11. Name one chemical which can arrest cell division at metaphase stage.
✓ Colchicine
12. How many pairs of homologous chromosomes are present in male *Drosophila*?
✓ 3 pairs of Autosomes and a pair of sex chromosomes.
13. Mention the number of chromosomes in Man and Chimpanzee.
✓ 23 pairs in humans and 24 pairs in Chimpanzee
14. Which caste of Honey Bee is produced parthenogenetically?
✓ Male
15. How many autosomes are found in a single mature human sperm?
✓ 22
16. How many types of gametes are formed by a double recessive parent?
✓ One
17. Who discovered Y-spot?
✓ Zech
18. Name one autosomal dominant and one autosomal recessive Mendelian disorder in humans.
(CBSE 2010)

19. Write the genotype of (i) An individual who is carrier of sickle cell anaemia gene but apparently unaffected, and (ii) An individual affected with the disease. (CBSE 2010)
20. A human being suffering from Down's syndrome shows trisomy of 21st chromosome. Mention the cause of this chromosomal abnormality. (CBSE 2010)
21. Name the event during cell division cycle that results in the gain or loss of chromosome. (CBSE 2011)
22. A garden Pea plant produced axial white flowers. Another of the same species produced terminal violet flowers. Identify the dominant traits. (CBSE 2012)
23. Name the respective pattern of inheritance where F_1 phenotype (a) does not resemble either of the two parents and is in between the two. (b) resembles only one of the two parents. (CBSE 2012)
24. In a dihybrid cross, when would the proportion of parental gene combinations be much higher than nonparental types, as experimentally shown by Morgan and his group.
25. What are 'true breeding lines' that are used to study inheritance pattern of traits in plants? (CBSE 2014)
26. Mention any two contrasting traits with respect to seeds in Pea plant that were studied by Mendel. (CBSE 2014)
27. Name the stage of cell division where segregation of an independent pair of chromosomes occurs. (CBSE 2014)
28. How many chromosomes do drones of honey bee possess ? Name the type of cell division involved in the production of sperms by them. (CBSE 2015)
29. A geneticist interested in studying variations and pattern of inheritance in living beings prefers to choose organisms for experiments with shorter life cycle. Provide a reason. (CBSE 2015)
30. Indiscriminate diagnostic practices using X-rays, etc. should be avoided. Give one reason. (CBSE 2015)
31. A male honeybee has 16 chromosomes whereas its female has 32 chromosomes. Give one reason. (CBSE 2016)
32. State a difference between a gene and an allele. (CBSE 2016)
33. Name the type of cross that would help to find the genotype of a pea plant bearing violet flowers. (CBSE 2017)
34. State the fate of a pair of autosomes during gamete formation. (CBSE 2017)

Two Mark Questions(With Sample Answers)

1. Do variations appear in clones also ? How ?
✓ Variations do appear even in the clones. They are of two types, acquired and mutations. The acquired variations are usually due to the effect of environment. They are not inherited. Differences appearing in monozygotic twins are also acquired variations. Mutations are sudden or discontinuous inheritable variations which are produced due to changes in the genetic constitution.
2. How light can cause variations in different plants and animals ?
✓ In the absence of light the plants remain etiolated. Shade produces elongated internodes and thinner and broader leaves. It increases the succulence of many vegetables. Strong light, on the contrary, helps in the production of more mechanical tissue and thicker leaves. Palisade parenchyma becomes multilayered under strong light but remains single layered under moderate intensities of light (e.g., Peach). The effect of light has also been observed by Cunningham in flat fish *Solea*. The fish habitually rests on left side. It develops pigmentation and eyes on right side, the side exposed to sun. If left side is exposed to sunlight in the young fish, both eyes and pigmentation develop on that side.
3. What do you understand by a phenotype and a genotype ? Explain by giving an example ?
✓ Genotype. The gene complement or genetic constitution of an individual with regard to one or more characters irrespective of whether the genes are expressed or not. For example, the genotype of hybrid tall Pea plant is Tt , pure tall TT and dwarf tt .
✓ Phenotype Is observable or measurable distinctive structural or functional characteristic of an individual with regard to one or more characters which is a result of gene products brought to expression in a given environment. For recessive genes, the phenotype is similar to genotype. For dominant genes, the phenotypic expression can be due to its homozygous genotype or heterozygous genotype. For example, phenotypic tall Pea plant can be genotypically TT or Tt .

4. Define F_1 & F_2 generations.

✓ **F_1 Generation.** F_1 or first filial generation is the generation of hybrids produced from a cross between the genetically different individuals called parents. For example, Tt individuals are produced in F_1 generation from a cross between TT and tt parents.

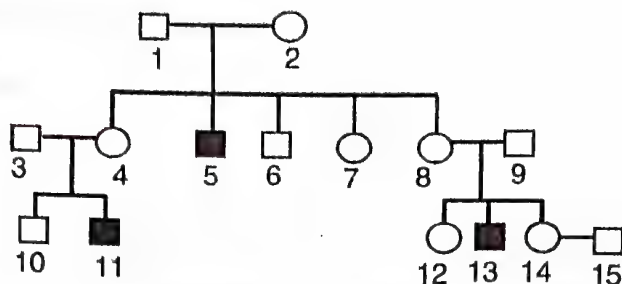
✓ **F_2 Generation.** F_2 second filial generation is the generation of individuals which arises as a result of inbreeding or interbreeding amongst individuals of F_1 generation.

5. What will be the genotypes of the parents if the offspring had phenotypes in the following proportion ?
(a) 9:3:3:1; (b) 1:1:1:1 (Use the symbols Aa and Bb).
✓ (a) AaBb × AaBb; (b) AaBb × aabb
6. *Drosophila* can have the following alleles for eye colour: red, white, apricot, eosine, wine, coral, cherry etc. Show by diagram, how many of these alleles will be present in one fly ?
✓ All these are multiple alleles of the same gene. An organism can not have more than 2 alleles of a gene at one locus.
7. How does a test cross help in identifying the genotype of the organism ? Explain (CBSE 2010)
8. When a tall Pea plant was self bred it produced one-fourth of the progeny as dwarf. Explain with the help of a cross. (CBSE 2010)
9. Why are F_2 phenotypic and genotypic ratios same in a cross between red-flowered *Snapdragon* and white flowered *Snapdragon* plants ? Explain with the help of a cross. (CBSE 2010)
10. A relevant portion of β -chain of haemoglobin of a normal human is
Val — His — Leu — Thr — Pro — Glu — Glu
1 2 3 4 5 6 7
The codon for the sixth amino acid is GAG. It mutates to GAA due to mutation 'A' and GUG due to mutation 'B'. Haemoglobin structure did not change as a result of mutation 'A' but mutation 'B' led to sickle cell-shaped RBCs. Explain giving reasons how could mutation 'B' change the haemoglobin structure and not mutation 'A'. (CBSE 2011)
11. A cross between a red flower bearing plant and a white flower bearing plant of *Antirrhinum* produced all plants having pink flowers. Work out a cross to explain how this is possible. (CBSE 2013)
12. In a typical monohybrid cross, the F_2 generation is written as 3 : 1 for phenotype but expressed as 1 : 2 : 1 for genotype. Explain with the help of an example. (CBSE 2013)
13. Work out a cross to find the genotype of a tall pea plant. Name the type of cross. (CBSE 2013)
14. How does gene I control ABO blood groups in humans? Write the effect of the gene on the structure of red blood cells. (CBSE 2014)
15. Write the type of sex determination mechanism the following crosses show. Give an example of each type. (i) Female XX and male XO (ii) Female ZW and male ZZ. (CBSE 2014)
16. A cross was carried out between two pea plants showing the contrasting traits of height of the plant. The result of the cross showed 50% of parental characters. (i) Workout the cross with the help of Punnett square. (ii) Name the type of cross carried out. (CBSE 2014)
17. With the help of one example explain the phenomenon of codominance and multiple allelism in human population. (CBSE 2014)
18. Write the Scientific name of fruitfly. Why did Morgan prefer to work with fruitflies for his experiments? State any three reasons. (CBSE 2014)
19. Linkage and crossing over of genes are alternatives of each other. Justify with the help of an example. (CBSE 2014)
20. In *Snapdragon*, a cross between true-breeding red flowered (RR) plants and true breeding white flowered (rr) plants showed a progeny of plants with all pink flowers. (a) The appearance of pink flowers is not known as blending. Why? (b) What is this phenomenon known as. (CBSE 2014)
21. Differentiate between male and female heterogamety ? (CBSE 2015)
22. Explain mechanism of sex determination in birds. (CBSE 2015)
23. Differentiate between ZZ and XY type of sex determination mechanism. (CBSE 2015)

Three Mark Questions (Short Answer Type)

1. Haemophilia is sex-linked recessive disorder of humans. The pedigree chart given below shows the inheritance of haemophilia in one family. Study the pattern of inheritance and answer the questions given (a) Given all the possible genotypes of the members 4, 5 and 6 in the pedigree chart

- (b) A blood test shows that the individual 14 is a carrier of haemophilia. The member numbered 15 has recently married numbered 14. What is the probability that their first child will be haemophilic male. (CBSE 2009)



2. Inheritance pattern of ABO blood groups in humans shows dominance, codominance and multiple allelism. Explain each concept with the help of blood group genotypes. (CBSE 2009)
3. Recently a girl baby has been reported to suffer from haemophilia. How is it possible? Explain with the help of a cross. (CBSE 2009)
4. In one family, each of the four children has a different blood group. Explain with the help of a cross. (CBSE 2009)
5. Who proposed chromosomal theory of inheritance? Point out any two similarities in the behaviour of chromosomes and genes. (CBSE 2009)
6. (i) Why are Grasshopper and *Drosophila* said to show male heterogamety? Explain. (CBSE 2010)
(ii) Explain female heterogamety with the help of an example.
7. Explain the process of artificial hybridisation to get improved crop variety in (i) Plants bearing bisexual flowers. (ii) Female parent producing unisexual flowers. (CBSE 2010)
8. Explain the mechanism of sex determination in insects like *Drosophila* and Grasshopper. (CBSE 2010)
9. During his studies on genes in *Drosophila* that were sex linked, T.H. Morgan found F_2 population phenotypic ratios deviated from expected 9 : 3 : 3 : 1. Explain the conclusion he arrived at. (CBSE 2010)
10. How are dominance codominance and incomplete dominance patterns of inheritance different from each other? (CBSE 2011)
11. (a) Sickle-cell anaemia in humans is a result of point mutation. Explain. (b) Write the genotypes of both the parents who have produced sickle-celled anaemic offspring. (CBSE 2011)
12. A plant with purple flowers was crossed with white flowers producing 50 plants with only purple flowers. On selfing these plants produced 482 plants with purple flowers and 162 plants with white flowers. What gametic mechanism accounts for these results? Explain. (CBSE 2011)
13. (a) Explain the phenomena of multiple allelism and codominance taking ABO blood group as an example. (b) What is the phenotype of (i) $I^A i$ (ii) ii . (CBSE 2012)
14. Why are human females rarely haemophilic? Explain. How do haemophilic patients suffer? (CBSE 2013)
15. Why is pedigree analysis done in the study of human genetics? State the conclusion that can be drawn from it. (CBSE 2014)
16. Identify a, b, c, d, e and f in the table

(i) Syndrome	Cause	Characteristic	Sex
Down's	Trisomy of 21	a - 1, a - 2	b
(ii) c	XXY	Overall masculine development	d
(iii) Turner's	45 with XO	e-1, e-2	f

 (CBSE 2014)
17. A colourblind child is born to a normal couple. Work out a cross to show how it is possible. Mention the sex of this child. (CBSE 2014)
18. Mendel published his work on inheritance of characters in 1865, but it remained unrecognised till 1900. Give three reasons for the delay in accepting his work. (CBSE 2014)

19. Women are often blamed for producing female children. Consequently they are ill treated and ostracized. How will you address this issue scientifically if you were to conduct an awareness programme to highlight the values involved? (CBSE 2014)
20. A cross between a normal couple resulted in a son who was haemophilic and a normal daughter. In course of time when the daughter was married to a normal man, to their surprise, the grandson was also haemophilic. (a) Represent this cross in the form of a pedigree chart. Give the genotypes of the daughter and her husband. (b) Write the conclusion you draw of the inheritance pattern of this disease. (CBSE 2014)
21. Two independent monohybrid crosses were carried out involving a tall pea plant with a dwarf pea plant. In the first cross, offspring population had equal number of tall and dwarf plants, whereas in the second cross it was different. Work out the crosses and explain giving reasons for the difference in the offspring populations. (CBSE 2015)
22. The F_2 progeny of a monohybrid cross showed phenotypic and genotypic ratios as 1 : 2 : 1 unlike that of Mendel's monohybrid F_2 ratio. With the help of a suitable example, work out a cross and explain how it is possible. (CBSE 2015)
23. (a) Name the kind of diseases/disorders that are likely to occur in human if,
 - (i) Mutation in the gene that codes for an enzyme phenylalanine hydrolase occurs.
 - (ii) There is an extra copy of chromosome 21.
 - (iii) The karyotype is XXY.
 (b) Mention any one symptom of the diseases/disorders named above. (CBSE 2015)
24. What is a test cross ? How can it decipher the heterozygosity of a plant ? (CBSE 2016)
25. Give an example of an autosomal recessive trait in humans. Explain its pattern of inheritance with the help of a cross. (CBSE 2016)
26. A couple with normal vision bear a colour blind child. Work out a cross to show how it is possible and mention the sex of the affected child. (CBSE 2016)
27. Both haemophilia and thalassemia are blood related disorders in humans. Write their causes and the difference between the two. Name the category of genetic disorder they both come under. (CBSE 17)
28. During a medical investigation, an infant was found to possess an extra chromosome 21. Describe the symptoms the child is likely to develop later in the life. (CBSE 2017)

Five Mark Questions (Long Answer Type)

1. Inheritance pattern of flower colour in Garden Pea and Snapdragon differs. Why is this difference observed. Explain showing the crosses upto F_2 generation. (CBSE 2009)
2. A particular garden Pea plant produces only violet flowers. How will you determine whether it is homozygous or heterozygous dominant. Explain with the help of crosses. (CBSE 2009)
3. (a) State the law of independent assortment.
(b) Using Punnett square demonstrate the law of independent assortment in a dihybrid cross involving two heterozygous parents. (CBSE 2010)
4. (a) How does a chromosomal disorder differ from a Mendelian disorder.
(b) Name any two chromosomal aberration associated disorders.
(c) List the characteristics of the disorders mentioned above that help in their diagnosis. (CBSE 2010)
5. Explain the causes, inheritance pattern and symptoms of any two Mendelian genetic disorders. (CBSE 2010)
6. Write the symptoms of haemophilia and sickle cell anaemia in humans. Explain how the inheritance pattern of the two diseases differ from each other. (CBSE 2010)
7. Describe the mechanism of pattern of inheritance of ABO blood groups in humans. (CBSE 2011)
8. (a) Why is haemophilia generally observed in human males. Explain the conditions under which a human female can be haemophilic.
(b) A pregnant human female was advised to undergo M.T.P. It was diagnosed by her doctor that the foetus she is carrying has developed from a zygote formed by an XX-egg fertilized by Y-carrying sperm. Why was she advised to undergo MTP ? (CBSE 2011)
9. (a) A true breeding homozygous Pea plant with green pods and axial flowers as dominant characters is crossed with a recessive homozygous Pea plant with yellow pods and terminal flowers. Work out the cross upto F_2 generation giving the phenotypic ratios of F_1 and F_2 generations respectively.

- (b) State the Mendelian principle which can be derived from such a cross and not from monohybrid cross. (CBSE 2011)
10. (a) Explain a monohybrid cross taking seed coat colour as a trait in *Pisum sativum*. Work out the cross upto F_2 generation.
(b) State the laws of inheritance that can be derived from such a cross.
(c) How is the phenotypic ratio of F_2 generation different in a dihybrid cross? (CBSE 2012)
11. (a) A garden Pea plant bearing terminal, violet flowers when crossed with another pea plant bearing axial violet flowers, produced axial violet flowers and axial white flowers in the ratio of 3 : 1. Work out the cross, showing the genotypes of the parent Pea plants and their progeny.
(b) Name and state the law that can be derived from this cross and not from a monohybrid cross. (CBSE 2012)
12. (a) Explain the mechanism of sex determination in humans.
(b) Differentiate between male heterogamety and female heterogamety with the help of an example of each. (CBSE 2013)
13. (a) Differentiate between dominance and codominance.
(b) Explain codominance taking an example of human blood groups in the population. (CBSE 2013)
14. (a) Explain Mendel's law of independent assortment by taking a suitable example.
(b) How did Morgan show the deviation in inheritance pattern in *Drosophila* with respect to this law? (CBSE 2013)
15. Workout a typical Mendelian dihybrid cross and state the law that he derived from it. (CBSE 2014)
16. (a) Why are thalassemia and haemophilia categorized as Mendelian disorders? Write the symptoms of these diseases. Explain their pattern of inheritance in humans?
(b) Write genotypes of normal parents producing a haemophilic son. (CBSE 2015)
17. (a) Why are colour blindness and thalassemia categorized as Mendelian disorders? Write the symptoms of these diseases seen in people suffering from them.
(b) About 8% of human male population suffers from colour-blindness whereas only about 0.4% of human female population suffers from this disease. Write an explanation to show how it is possible. (CBSE 2015)
18. (a) How are Mendelian inheritance, polygenic inheritance and pleiotropy different from each other?
(b) Explain polygenic inheritance with a suitable example. (CBSE 2015)
19. Explain the genetic basis of blood grouping in human population. (CBSE 2015)
20. (a) What is polygenic inheritance? Explain with the help of a suitable example.
(b) How are pleiotropy and Mendelian pattern of inheritance different from polygenic inheritance? (CBSE 2016)
21. State and explain the "law of independent assortment" in a typical Mendelian dihybrid cross. (CBSE 2017)
22. (a) Explain polygenic inheritance and multiple allelism with the help of suitable examples.
(b) Phenylketonurin is a good example that explains pleiotropy. Explain. (CBSE 2017)
23. (a) A pea plant bearing axial flowers is crossed with a pea plant bearing terminal flowers. The cross is carried out to find the genotype of pea plant bearing axial flowers. Work out the cross to show the conclusions you arrive at.
(b) State Mendel's law of inheritance that is universally acceptable. (CBSE 2017)

Miscellaneous

1. Fill in the blanks:
(a) The _____ or gene constitution of an individual heterozygous for L is written as _____.
(b) The dihybrid ratio of 9 : 3 : 3 : 1 proves the law of _____ enunciated by _____.
2. (a) Name the plant that shows incomplete dominance with respect to colour of its flower.
(b) What do the following genetic symbol stand for: AA, Aa.
3. If the distance between the genes on a chromosome is as follows, prepare a genetic map, assigning the correct order of genes.
a _____ b = 5 cM
b _____ c = 3 cM
a _____ c = 2cM

4. What will happen :
- (i) When complete sets of chromosomes are added to diploid genome ?
 - (ii) When individual chromosomes are added to or deleted from the diploid genome ?
 - (iii) When a part of the chromosome is lost ?
 - (iv) When a part of the chromosome breaks and attaches to another non-homologous chromosome.
 - (v) When a part of the chromosome breaks and attaches to its homologue ?

Value Based Question

- Why is it said that marriages between close relatives is fraught with danger for the next generation.
 ✓ Human beings have many hundred recessive traits which in homozygous state cause hereditary diseases. Being noninfective, the hereditary diseases are nearly incurable. The only way to avoid them is to try for nonappearance of these harmful traits in homozygous state. In the heterozygous condition, the recessive traits remain suppressed due to presence of dominant alleles. Homozygosity is more common if marriages are performed between relatives of 4-6 generations. The same should, therefore, be avoided. Out crossing or marriages between unrelated individuals for 4-6 generations will continue heterozygosity in the offspring.
- Siblings do not resemble each other despite being born to the same parents. How and why? What conclusion do we derive from the same?
 ✓ Despite being born to the same parents, siblings do not resemble each other due to (i) Chance separation of chromosomes during gamete formation. (ii) Recombination of genes due to crossing over of chromosome segments at the time of gametogenesis. (iii) Chance coming together of parental chromosomes at the time of syngamy.
 Differences between siblings are called **variations**. Variations are an important tool in the struggle for existence, competitive success, competitive exclusion, adjustments in family and society and our adaptability at various levels.
- Mohan has two daughters. He blames his wife for bearing only daughters and no son. How will you convince Mohan that his wife has no role in giving birth to daughters only so that she should not be blamed for it. Further, females are rather more important component of society. What values are involved in this advice.
 ✓ You can explain to Mohan, that sex of a child is determined at the time of conception. Women are homogametic, that is, they will produce only one type of ova ($22 + X$). Men are heterogametic. They produce two types of sperms in equal proportion, androsperms ($22 + Y$) and gynosperms ($22 + X$). It is a matter of chance that the ovum is fertilized by an androsperm or a gynosperm. The same chance can occur two, three, or more times. But for any chance, the wife cannot be blamed. It is the father which is responsible for the sex of the child.
 Mohan can further be told that women are more important part of the family as well as society. A woman is not only the caretaker of the child. She is also the first and real teacher of the baby. She is responsible for upkeep and care of the family and its acquaintances. Educated and working women not only share social responsibilities but also add to the income of the family.

Multiple Choice Questions

- A sex-linked disorder is (a) Albinism (b) Phenylketonuria (c) Haemophilia (d) Sickle cell anaemia.
(Manipur 2009)
- Alzheimer disease is associated with deficiency of (a) Dopamine (b) Glutamic acid (c) GABA (d) Acetylcholine.
(CBSE 2009)
- Human blood grouping is called ABO instead of ABC because O signifies (a) No antigen (b) Overdominance (c) One antibody (d) Other antigen.
(CBSE 2009)
- Which of following genotype does not produce any oligosaccharide on the surface of RBCs ?
(a) $I^A I^A$ (b) $I^B i$ (c) $I^A I^B$ (d) i, i (e) $I^B I^B$.
(Kerala 2010)
- In *Antirrhinum* two plants with pink flowers were hybridised. The F_1 plants produced red, pink and white flowers in the proportion of 1 red, 2 pink and 1 white. What could be the genotype of the two plants used for hybridisation ? Red flower colour is determined by RR and white by rr genes.
(a) rr (b) Rr (c) RR (d) $rrrr$.
(CBSE Mains 2010)
- Which one of the following symbols and its representation used in human pedigree analysis is correct
(a) \bigcirc = unaffected male (b) \square = unaffected female (c) \blacklozenge = male affected (d) $\square=\bigcirc$ = mating between relatives.
(CBSE 2010)

- (7) Which condition describes the sex correctly (a) XO condition as in Turner's syndrome determines the female sex (b) XX sex chromosomes produce male in *Drosophila* (c) ZZ sex chromosomes determine female sex in birds (d) XO sex chromosomes determine male sex in Grasshopper. (CBSE 2011)
- (8) Which condition of zygote cell will lead to birth of a normal human female child (a) one X-chromosome (b) one X and one Y chromosome (c) two X-chromosomes (d) one Y-chromosome. (CBSE Mains 2011)
- (9) A normal visioned man whose father was colour blind, marries a woman whose father was also colour blind. They have their first child as a daughter. What are the chances that this child would be colour blind (a) 100% (b) zero percent (c) 25% (d) 50%. (CBSE 2012)
- (10) A test cross is carried out to (a) predict whether two traits are linked (b) assess the number of alleles of a gene (c) determine the genotype of F_2 plant (d) determine whether two species or varieties will breed successfully. (CBSE Mains 2012)
- (11) Which mendelian idea is depicted by a cross in which F_1 generation resembles both the parents (a) Codominance (b) Incomplete dominance (c) Law of dominance (d) Inheritance of one gene. (NEET 2013)
- (12) If both the parents are carriers of autosomal recessive disorder thalassemia, what are the chances of pregnancy resulting in an affected child (a) 100% (b) 50% (c) 25% (d) No chance. (NEET 2013)
- (13) Fruit colour in squash is an example of (a) recessive epistasis (b) dominant epistasis (c) complementary genes (d) inhibitory genes. (CBSE 2014)
- (14) A human female with Turner's syndrome (a) has an additional X-chromosome (b) is able to produce children with normal husband (c) exhibits male characters (d) has 45 chromosomes with XO. (CBSE 2014)
- (15) Trisomy 18 is (a) Edward's syndrome (b) Patau's syndrome (c) Turner's syndrome (d) Klinefelter's syndrome. (AMU 2015)
- (16) A male rabbit of genotype AA BB DD EE is crossed with female rabbit of genotype aa bb dd ee to produce F_1 hybrid offspring. How many genetically different gametes can be produced by this F_1 hybrid (a) 4 (b) 8 (c) 16 (d) 32. (W. B. 2015)
- (17) A colour blind man marries a woman with normal sight who has no history of colour blindness in her family. What is the probability of their grandson becoming colour blind (a) 0.5 (b) 1 (c) Nil (d) 0.25. (CBSE 2015)
- (18) A tall true breeding garden pea plant is crossed with a dwarf true breeding garden pea plant. When the F_1 plants were selfed the resulting genotypes were in the ratio of (a) 1 : 2 : 1 :: Tall heterozygous : Tall homozygous : dwarf (b) 3 : 1 :: Tall : Dwarf (c) 3 : 1 :: Dwarf : Tall (d) 1 : 2 : 1 :: Tall homozygous : Tall heterozygous : Dwarf. (NEET I 2016)
- (19) Match the terms in Column I with their description in Column II and choose the correct option :

Column I

- (a) Dominance
(b) Codominance
(c) Pleiotropy
(d) Polygenic inheritance

Column II

- (i) Many genes govern a single character
(ii) In a heterozygous organism only one allele expresses itself.
(iii) In a heterozygous organism both alleles express themselves fully.
(iv) A single gene influences many characters

Code :	(A)	(B)	(C)	(D)
(a)	(ii)	(iii)	(iv)	(i)
(b)	(iv)	(i)	(ii)	(iii)
(c)	(iv)	(iii)	(i)	(ii)
(d)	(ii)	(i)	(iv)	(iii)

- (20) A cell at telophase stage is observed by a student in a plant brought from the field. He tells his teacher that this cell is not like other cells at telophase stage. There is no formation of cell plate and thus the cell is containing more number of chromosomes as compared to other dividing cells. This would result in (a) polyploidy (b) somaclonal variation (c) polyteny (d) aneuploidy. (NEET I 2016)
- (21) Thalassemia and sickle cell anaemia are caused due to a problem in globin molecule synthesis. Select the correct statement. (NEET I 2016)

- (a) Both are due to a quantitative defect in globin chain synthesis (b) Thalassemia is due to less synthesis of globin molecules (c) Sickle cell anaemia is due to a qualitative problem of globin molecules (d) Both are due to a qualitative defect in globin chain synthesis. (NEET 2017)
- (22) The genotypes of a husband and wife are $I^A I^B$ and $I^A i$. Among the blood types of their children, how many different genotypes and phenotypes are possible ?
 (a) 3 genotypes ; 4 phenotypes (b) 4 genotypes ; 3 phenotypes (c) 4 genotypes ; 4 phenotypes (d) 3 genotypes ; 3 phenotypes. (NEET 2017)
- (23) Which one from those given below is the period for Mendel's hybridisation experiments ?
 (a) 1840–1850 (b) 1857–1869 (c) 1870–1877 (d) 1856–1863 (NEET 2017)
- (24) Homozygous purelines in cattle can be obtained by (a) mating of unrelated individuals of same breed (b) mating of individuals of different breed (c) mating of individuals of different species (d) mating of related individuals of same breed. (NEET 2017)
- (25) Among the following characters, which one was not considered by Mendel in his experiments on pea?
 (a) Trichomes—Glandular or non-glandular (b) Seed—Green or yellow (c) Pod—Inflated or constricted (d) Stem—Tall or dwarf. (NEET 2017)
- (26) A disease caused by an autosomal primary non-disjunction is (a) Klinefelter's syndrome (b) Turner's syndrome (c) Sickle cell anaemia (d) Down's syndrome. (NEET 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given. One is assertion (A) and one is reason (R). Mark the correct answer as

- (A) If both A and R are true and R is correct explanation of A.
 (B) If both A and R are true but R is not the correct explanation of A.
 (C) If A is true but R is false. (D) If both A and R are false

- Assertion :** Phenylketonuria is a recessive hereditary disease caused by failure of the body to oxidise an amino acid phenylalanine to tyrosine because of defective enzyme. (AIIMS 2007)
Reason : It results in presence of phenylalanine in urine.
 (A) (B) (C) (D)
- Assertion :** A genetist crossed two plants. He got 50% tall and 50% dwarf plants in the progeny.
Reason : One parent was heterozygous tall while the other was dwarf. (AIIMS 2011)
 (A) (B) (C) (D)
- Assertion :** $Hb^S Hb^S$, is homozygous condition of sickle cell anaemia. (AIIMS 2012)
Reason : It occurs due to substitution of glutamic acid by valine at 6th position of β -chain of haemoglobin.
 (A) (B) (C) (D)
- Assertion :** A middle aged woman is having small sized breasts and undersized uterus.
Reason : Her genotype shows XO condition of allosomes. (AIIMS 2012)
 (A) (B) (C) (D)
- Assertion :** Only a boy child could be born with the substitution of glutamic acid by valine on 6th position of β -chain of haemoglobin.
Reason : The gene for the above mutation occurs in Y-chromosome. (AIIMS 2013)
 (A) (B) (C) (D)
- Assertion :** In a pedigree analysis, $\diamond 5$ represents five unaffected offspring.
Reason : In the pedigree analysis, the offspring are numbered with arabic numerals (1, 2, 3.....) and a generation is numbered with roman numerals. (AIIMS 2014)
 (A) (B) (C) (D)
- Assertion :** XX-XY type of sex determination mechanism is an example of male heterogamety.
Reason : In birds, male heterogamety is observed as males produce two different types of gametes. (AIIMS 2015)
 (A) (B) (C) (D)
- Assertion :** Number of chromosomes in one genome is equal to number of linkage groups.
Reason : Linkage groups give important information about location of genes in the chromosomes. (AIIMS 2015)
 (A) (B) (C) (D)
- Assertion :** XX-XY type of sex determination mechanism is an example of female heterogamety and is found in *Drosophila*.

Reason : Male heterogamety is seen in moths where males produce two different types of gametes.
(A) (B) (C) (D) (AIIMS 2017)

ANSWERS

Miscellaneous Answers

1. (a) genotype, LI (b) independent assortment, Mendel
2. (a) *Mirabilis jalapa*/*Antirrhinum* (b) AA— homozygous dominant, Aa—heterozygous dominant

Multiple Choice Questions

- (1) —c (2) —d (3) —a (4) —d (5) —b (6) —d (7) —d (8) —c (9) —b (10) —c
(11) —a (12) —c (13) —b (14) —d (15) —a (16) —c (17) —a (18) —d (19) —a (20) —a
(21) —b (22) —b (23) —d (24) —d (25) —a (26) —d

Assertion and Reason Type Questions

- (1) —A (2) —A (3) —B (4) —A (5) —D (6) —B (7) —C (8) —B (9) —D

IMPORTANT TERMS

Nucleic Acids. Nucleic acids, first called "nuclein" because they were isolated from cell nuclei by F. Miescher in 1869.

Deoxyribonucleic acid (DNA). DNA is a genetic material in all living organisms and many viruses. In DNA, the sugar is deoxyribose (thus the name deoxyribo-nucleic acid).

Ribonucleic acid (RNA). RNA is genetic material in certain viruses such as the AIDS virus, influenza virus and Tobacco Mosaic Virus (TMV). In RNA, the sugar is ribose (thus the name ribonucleic acid). RNA usually contains purines (adenine and guanine) and pyrimidines (cytosine and a different base, **uracil** in place of thymine). Phosphoric acid is found as phosphate. RNA is usually a single stranded molecule.

Genomic or Genetic RNA (gRNA). gRNA contains hereditary information in riboviruses* and viroids**. Discovered by Fraenkel Conrat (1957).

Messenger RNA (mRNA). RNA that carries information necessary for protein synthesis from the DNA to the ribosomes.

Transfer RNA (tRNA). RNA that transports amino-acids to the ribosomes where the amino acids are assembled into proteins.

Ribosomal RNA (rRNA). RNA that provides sub cellular structure to the ribosomes. It is nonspecific for amino acids. RNA is also a catalytic molecule in some cases.

Nucleoside. Portion of a DNA or RNA molecule composed of one deoxyribose molecule (in DNA) or ribose (in RNA), plus a purine or a pyrimidine.

Nucleotide. A monomeric unit from which DNA and RNA is constructed. It consists of a purine or pyrimidine base, a pentose and phosphoric acid.

Purines. Two ringed nitrogenous bases, *e.g.*, adenine (A), guanine (G). Both are found in DNA and RNA.

Pyrimidines. One ringed nitrogenous bases, *e.g.*, thymine (T), Uracil (U) and cytosine (C). Thymine is found in DNA, uracil in RNA and cytosine in both DNA and RNA.

Helix (pl. helices). Any structure with a spiral shape. The Watson and Crick model of DNA is in the form of a double helix.

Base pair. Base pair (bp) is a pair of nitrogenous bases most commonly one purine and one pyrimidine that are connected through hydrogen bonds in a double stranded region of a nucleic acid molecule. The normal base pairs in DNA are A-T and G-C.

Base Ratio. It is the ratio between the sum total of adenine (A) + thymine (T) and the total of guanine (G) + Cytosine (C) in a DNA sample.

Glycosidic bond (N-glycosidic linkage). A linkage between a nitrogenous base and a pentose sugar to form a nucleoside is called **glycosidic bond**.

* Viruses in which genetic material is RNA.

** Viroids are infectious RNA particles which are devoid of protein coat.

Antiparallel. A term used to refer to the opposite but parallel arrangement of the two sugar-phosphate strands in double-stranded DNA, one strand is oriented in the $5' \rightarrow 3'$ direction and the other strand in the $3' \rightarrow 5'$ direction.

Uridine. The ribonucleoside that contains the pyrimidine uracil.

Uridylic acid. The ribonucleotide that contains the pyrimidine uracil.

Bacteriophage. It is a virus whose host is a bacterium. It is commonly called **phage**. It destroys its bacterial host.

Phosphodiester bond. The bond between two adjacent nucleotides of two adjacent sugar molecules at $3'$ and $5'$ positions with phosphate group.

Template. A model mould (US mold) or pattern. One strand of DNA acts as a template for messenger RNA synthesis.

Histones. Histones are a set of positively charged basic proteins associated with DNA helix.

Nucleosome. The bead-like structure of eukaryotic chromatin fibres is called **nucleosome**. It is a complex structure consisting of negatively charged DNA wrapped around the positively charged **histone octamer** (the core particle or **nu body**). DNA of about 200 bp makes two (1.75) circles over the histone octamer. The histone octamer consists of eight histone protein molecules. Two adjacent nucleosomes are connected by **linker DNA** or **interbead DNA** like beads on a string. The term nucleosome was coined by **Oudet et al** (1975).

Codon. A triplet (group of three) of nitrogenous bases on mRNA that codes for a particular amino acid in protein synthesis.

Anticodon. A triplet of nitrogenous bases present on tRNA that is complementary to the codon of mRNA for the particular amino acid in protein synthesis.

Initiation or Start Codon. The codon AUG is called the initiation or start codon as it begins the synthesis of polypeptide chain. In certain rare instances among the prokaryotes, the codon GUG may serve as a start codon.

"Nonsense" or "Termination Codons". Three codons, namely, UAA, UAG and UGA are called the **"nonsense" or termination codon**. Either of these codons stops synthesis of polypeptide chain.

Replication. It is a duplication process requiring copying from a template. It occurs in case of DNA.

Transcription. The synthesis of RNA from a DNA template is termed as transcription.

Transcription Unit. It is the segment of DNA that takes part in transcription.

Transduction. It is the transfer of bacterial genetic material from one bacterium to another using a phage (e.g., bacteriophage) as a vector **Zinder** and **Lederberg** discovered transduction.

Translation. It is the synthesis of protein (polypeptide), directed by a specific messenger RNA. It occurs on ribosomes.

Lagging Strand. The strand of DNA that replicates discontinuously and lags behind the other.

Leading Strand. The strand of DNA that replicates continuously and ahead of other strand.

Okazaki fragments. Newly synthesized short fragments of DNA that are formed on the lagging strand of DNA during DNA replication. These were named after the scientist Okazaki who discovered them in 1968.

Primer. This is a short RNA segment formed on DNA template prior to the beginning of replication.

DNA ligase. An enzyme that joins newly synthesized fragments of DNA (Okazaki fragments) are joined together by enzyme DNA ligase). DNA ligase was discovered by **Khorana** in 1967.

DNA polymerase. An enzyme that is responsible for forming new copies of DNA. DNA polymerase was discovered by **Kornberg** (1957).

Cistron. A unit of function in DNA that determines a single polypeptide chain in protein synthesis (functional unit of a DNA molecule).

RNA polymerase. An enzyme that acts as a catalyst in the formation of RNA from one strand of DNA.

Holandric Gene. A gene carried on the γ -chromosome and therefore, transmitted from father to son.

Central dogma*. It states that genetic information flows from DNA to RNA and thence to polypeptide (protein).

Operon. Operon is a segment of DNA that consists of one or more adjacent structural genes, an operator gene, a promoter gene and a regulator gene. Operon works in co-operation with a repressor protein and an inducer substance.

Exons. Exons are the regions of a gene, which become part of mRNA and code for the different regions of proteins.

Introns. Introns are the regions of a gene, which do not form part of mRNA and are removed during the processing of mRNA.

Splicing. It is a process in eukaryotic genes whereby the introns are removed and the exons are joined together to form mRNA.

Poly-A tail. A sequence of adenosine nucleotides added to the 3' end of many eukaryotic messenger RNAs.

CpDNA. Chloroplast DNAs are circular like those of mitochondria. Also abbreviated chDNA.

Electrophoresis. The movement of the charged molecules in solution in an electrical field.

DNase (Deoxyribonuclease). It is an enzyme that digests DNA to oligonucleotides or nucleotides by cleaving the phosphodiester bonds.

Amplification. It refers to the process of making a number of copies of a given DNA/DNA segments.

Southern blotting. This technique is named after its inventor **E. M. Southern**. It is a technique of the transfer of DNA fragments from an electrophoretic gel to a cellulose or nylon membrane by capillary action. Transfer is achieved by capillary action, hence the term **blotting** is used.

Northern blotting. It is similar to Southern blotting which can be used to detect RNA molecules. Instead of DNA, RNA is transferred from the gel to a membrane in a similar way to that described for DNA transfer.

Western blotting. The transfer of *proteins* from an electrophoretic gel to a cellulose or nylon membrane by means of an electric force.

Genetic Material. The substance which stores genetic information, transfers it to the next generation and causes its expression in the offspring is called **genetic material**.

Chargaff's Rules. Its most important point is that in any sample of DNA the amount of adenine equals the amount of thymine and the amount of guanine equals the amount of cytosine (*i.e.*, equal purine and pyrimidine content). It is a consequence of the base pairing.

Retro viruses. A group of viruses possessing RNA as a genetic material. These viruses carry the gene for reverse transcription, *i.e.*, RNA \rightarrow DNA.

Transformation. The process by which DNA isolated from one type of cells is introduced into another type and that inherits some of the properties from former to the latter. **Frederick Griffith** discovered the phenomenon of transformation.

****Tandem Repeat.** A DNA segment in which a nucleotide sequence is repeated one after another two or more times. For example, the sequence ATGGCATGGCATGGC is a tandem repeat in which the sequence ATGGC is repeated three times.

Transposons (Jumping genes). Some repetitive DNA sequences change their position in

*Dogma means belief, to be accepted as true without question.

**Tandem means one behind the other.

the DNA. These are called transposons or jumping genes. They were first discovered by **Mcclintock** in 1951 in maize.

Genetic code. Genetic code is defined as a correspondence between (a) the sequence of nucleotides in DNA or mRNA and (b) the sequence of amino acids in polypeptides during protein synthesis. The term was coined by **George Gamow (1954)**. He also suggested **triplet code**.

In vitro. From the Latin, meaning 'within glass' biological processes made to occur experimentally outside the organism in a test tube or other container. *In vitro* synthesis of DNA was first performed by **Kornberg (1959)**.

In vivo. From the Latin, meaning 'within the living organism'.

Stem Cell. A mitotically active somatic cell from which other cells arise by differentiation.

***Wobble Hypothesis.** This hypothesis was proposed by **Crick** in 1966. It states that the first two bases of the tRNA anticodon undergo hydrogen bonding specifically with the first two bases of the mRNA codon but the third base can undergo unusual base pairing, i.e., it can "wobble". The third position in the codon is, therefore, called **wobble position**.

Polymer. A substance having large molecules consisting of repeated units (the monomers) is called polymer. Proteins, nucleic acids (DNA and RNA) and polysaccharides (cellulose and starch in plants and glycogen in animals) are good examples of polymers.

Residue. In biochemistry, referring to a small subunit that forms a component of a larger molecule.

Transforming Principle. The transforming principle was an early name for genetic material (DNA).

Semiconservative Replication. It is a method of replication of DNA in which the molecule divides longitudinally, each half being conserved and acting as template for the formation of a new strand.

Semidiscontinuous Replication. It is a mode of DNA replication in which one new strand is synthesized continuously, while the other is synthesized discontinuously, as Okazaki fragments.

Polyadenylation. It is an addition of a **polyA tail** at 3' end of hnRNA (heterogenous nuclear RNA) with the help of poly A polymerase. The polyA tail contains adenine residues (about 200-300). Polyadenylation is thought to protect the 3' end from degradation by exonucleases.

He La Cells. Cells originally from a carcinoma (cancer) of the cervix, cultured since 1951. "He La" is derived from the patient named **Henrietta Lacks**.

Archibald Garrod is "Father of Physiological Genetics" or "Father of Biochemical Genetics".

Polymerase Chain Reaction (PCR). A method of selectively amplifying regions of DNA by *in vitro* replication involving repeated denaturation and renaturation of the DNA template. PCR was invented by **Kary Mullis**.

Prions. Infectious pathogens that cause neurodegenerative diseases such as the Creutzfeldt-Jakob (CJ) disease in humans, scrapie** of sheep and bovine spongiform encephalopathy ("mad cow disease"). Prions are transmissible particles at least 100 times smaller than viruses and are composed exclusively of special low molecular weight infectious proteins having neither RNA nor DNA. **Stanley Prusiner** discovered 'Prions'.

Thus organic molecule such as prion, other than nucleic acids, can replicate.

Rho factor. An oligomeric protein in *E. coli* that attaches to certain sites on its DNA to assist in termination of transcription.

Rous Sarcoma Virus (RSV). The first oncogenic virus to be discovered. It is named after **Peyton Rous** who showed that it caused tumours in chickens. The RSV was one of the first retroviruses shown to produce a reverse transcriptase.

* **Wobble.** To move unsteadily from side to side.

**Scrapie – a serious disease of sheep.

Sigma (σ) Factor. A polypeptide subunit of the RNA polymerase of *E. coli*. This molecule by itself has no catalytic function, but it serves to recognize specific binding sites on DNA molecules for the initiation of RNA transcription.

Structural Gene. A gene that codes for a protein or an RNA product, but is not a regular gene.

Replication Fork (Y Fork). The point at which a dsDNA molecule is being replicated, the two template strands of the parental molecule separate, forming the arms of a Y-shaped structure.

mtDNA. Mitochondrial DNA.

Karyotype. The chromosomal display of a cell, individual or species. The karyotype is often illustrated with a figure showing the chromosomes placed in order from largest to smallest.

Kuru. A chronic progressive degenerative disorder of the central nervous system. The disease was at one time thought to be genetically determined but it is now believed to be caused by a prion.

Linker DNA. A linker DNA connects the adjacent nucleosomes.

TATA box pronounced as "tah-tah", the same thing as the Hogness box (named after its discoverer Hogness) and Pribnow box (named after its discoverer Pribnow). It is a site of attachment of RNA polymerase.

Genomics. A field of genetics concerned with the study of the structure, function and evolution of whole genomes. The term genomics was introduced by **Thomas Roderick**.

Nuclein. The acidic phosphorus-rich substance isolated from human white blood cells by **Miescher**. We now know that nuclein was a mixture of nucleic acids and proteins.

Agar. A polysaccharide extract of certain sea weeds used as a solidifying agent in culture media.

Agrose. A carbohydrate polymer that is a component of agar. It is used in chromatography and electrophoresis.

Kilobase. A unit of length for nucleic acids consisting of 1000 nucleotides abbreviated Kb or Kbp for kilobase pairs (DNA).

Phage. An abbreviation of bacteriophage, a virus that attacks bacteria.

Nanometer (nm) = 10^{-9} meter or 10 \AA (Angstroms).

Nascent RNA. Newly synthesized RNA molecule.

Null mutation. A mutation that abolishes the expression of a gene.

cDNA. It stands for complementary DNA, a synthetic type of DNA generated from mRNA.

Repetitive DNA. A small stretch of DNA is repeated many times in genome.

Satellite DNA. It is highly repetitive DNA which forms a separate fraction during ultracentrifugation.

C-value. Total amount of DNA per genome.

Picogram (pg). The amount of DNA is expressed in picogram $1 \text{ pg} = 10^{-12} \text{ gm}$.

Actinomycin D. Inhibits transcription.

Puromycin. Inhibits translation.

Oncogene. A gene that induces uncontrolled cell proliferation.

Ribozyme and RNase P are two non-protein enzymes.

X-ray Crystallography. A technique for determining the three-dimensional structure of a large molecule.

X-ray diffraction pattern. The pattern obtained after the diffraction of X-ray through a crystal.

Restriction endonuclease. Any of a group of enzymes that breaks internal bonds of a DNA at highly specific points.

UTRs (Untranslated Regions). UTRs are those additional regions of mRNA that are not translated but are required for efficient translation process.

DNA polymorphism. It is a form of polymorphism in which there is variation in DNA sequence at a given genomic site among individuals of a population.

SNP (Single Nucleotide Polymorphism). It is a type of DNA polymorphism consisting of small variations in DNA sequence, in which at any given position in the genome a single nucleotide pair is replaced by one of the other three pairs.

VNTRs (Variable Number Tandem Repeats). It is a type of DNA polymorphism in which tandem repeats found at specific loci in the genome show variation in the number of repeating units between individuals of a population. VNTRs are also called **minisatellites**.

RFLP (Restriction fragment length polymorphism). It is a type of DNA polymorphism in which there is variation between individuals of a species in the banding pattern of DNA fragments generated when DNA samples from individuals are cleaved by a restrictive nuclease.

p⁵³. It is a tumour suppressing protein. This protein is expressed in most normal tissues. Absence of p⁵³ can cause more than 50% of human cancers. p⁵³ is described as the 'Guardian of the genome'

Operator Gene. That regulates the activity of structural genes.

Promoter Gene. To which an RNA polymerase binds and initiates transcription.

Regulator Gene. That codes for an RNA or a protein product, which activates or represses the expression of other genes.

Repressor. A protein (synthesized by a regulator gene) that binds to an operator locus and blocks transcription of that operon.

Inducer. A substance of low molecular weight that inactivates a repressor by combining with it, thereby stimulating gene expression.

Co-repressor. It is a nonproteinaceous small molecule (usually an end product of a metabolic pathway) that binds with the repressor protein to form a functional repressor complex which inhibits transcription of genes in an operon. Corepressor is also called a **repressing metabolite**.

Aporepressor. It is a regular protein which combines with the corepressor and the aporepressor-corepressor complex acts as repressor and joins the operator gene which is turned off. Now the structural genes inhibit transcription in an operon.

Autoradiography. A method by which a radiolabeled molecule such as DNA or RNA or a structure such as a chromosome produces an image on photographic film. The image is called an auto-radiogram or autoradiograph.

Probe. A labelled (with radioactive isotopes) molecule, frequently DNA or RNA, that is used for hybridization.

Nucleic Acid Hybridization. Formation of a double stranded hybrid by base pairing between complementary polynucleotides.

DNA Fingerprinting. A method used to identify individual DNA banding patterns derived from hypervariable regions of DNA; used in forensics, to establish paternity and in conservation biology. DNA fingerprinting is based upon **principle of polymorphism** in DNA sequence.

Capsid. It is the protein coat of a virus which wraps the genetic material.

Bioinformatics. A new field in which computer hardware and software technologies are developed and used to gather, store, analyze and disseminate biological data, images and other information.

NOBEL PRIZE WINNERS RELATED TO GENETICS

Name of Scientist(s)	Year	Topic of study or discovery
T. H. Morgan	1933	Role of Chromosomes in heredity.
Hermann Joseph Muller	1946	Production of mutations by X-ray irradiations in <i>Drosophilla</i> . (CBSE 1994; BHU 89,92; MPPMT 97)
Beadle, Tatum and Lederberg	1958	One gene one enzyme concept by Beadle and Tatum. Lederberg gave genetic recombination and organization of genetic material of bacteria. (BHU 1995; CBSE 1992; UCPMT 1991)
Ochoa and Kornberg	1959	In vitro synthesis of RNA by Ochoa and DNA by Kornberg. (UCPMT 1991)
Crick, Watson and Wilkins	1962	Double helical model of DNA and significance for information transfer in living material. (CBSE 1994)
Jacob, Andre Lwoff and Monod	1965	Operon concept, genetic regulation of enzyme action. (MPPMT 1987)
Har Gobind Khorana, Holley and Nirenberg	1968	Har Gobind Khorana and Nirenberg for discovery of genetic code and its function in protein synthesis and Holley for giving structure of the RNA. (MPPMT 1990; AIIMS 1990)
Baltimore, Temin and Dulbecco	1975	Reverse transcription in Rous Sarcoma virus (RSV) was discovered by Baltimore and Temin and tumour viruses (Oncogenic viruses) as causative agent of cancer by Dulbecco. (BHU 1988)
Arber, Nathans and Smith	1978	Restriction endonucleases , enzymes that break giant molecules of DNA into manageable pieces and produce sticky ends. (AIIMS 1989, DPMT 1988, UCPMT 1995, MPPMT 1990, 97; BHU 1985, 89, 95)
Sanger	1980	Nobel Prize in chemistry twice — one for structure of insulin (1958) and second time for base sequence in DNA (1980). (BHU 1989)
Paul Berg	1980	In chemistry. He was able to introduce a gene of SV-40 virus into a bacterium.
Barbara Mc Clintock	1983	She is called Lady Mendel as she was first lady geneticist. She discovered mobile genetic elements (Floating genes or Jumping genes or Transposons) in Maize. (UCPMT 1985, AIIMS 1984, 85 CBSE 1990)
Cech and Altmann	1989	Nobel Prize in chemistry for the remarkable discovery of RNA acting as catalytic enzyme and thus the monopoly of enzyme to be protein is changed. Ribozyme and RNase-P are two such non-protein enzymes. (BHU 1995)

Bishop and Varmus	1989	Discovered Oncogenes related with cancer.
K. B. Mullis	1993	In Chemistry; invention of the PCR (Polymerase Chain Reaction) method.
Roberts and Sharp	1993	For the discovery of split genes.
Lewis, C. Nusslein-Volhard and Wieschaus	1995	The discoveries concerning the genetic control of early embryonic development.
Stanley B. Prusiner	1997	He discovered 'Prions' which are proteinaceous infective particles having neither RNA nor DNA.
Andrew Z. Fire and Craig C. Mello	2006	For their discovery of RNA interference (RNAi)—gene silencing by double-stranded RNA (dsRNA)
Elizabeth H. Blackburn, Carol W. Greider and Jack Szostak	2009	Awarded for the discovery of how chromosomes are protected by telomeres and the enzyme telomerase.
Jeffrey Hall, Michael Rosbash and Michael Young	2017	They used fruit flies to isolate a gene that controls the normal daily biological clock and showed how this gene encoded a protein that accumulates in the cell during the night and degrades during the day. The biological clock regulates critical functions such as behaviour, hormone levels, sleep, body temperature and metabolism.

Introduction

In the previous chapter, "Principles of Inheritance and Variations", you have studied the patterns of inheritance and their genetic basis. In this chapter you will study the structure and function of genetic material.

DNA acts as the genetic material in most of the organisms. RNA though acts as a genetic material in some viruses, mostly functions as a messenger carrying genetic information. RNA has also additional roles. It functions as adapter for picking up amino acids and assembly point (ribosome) for synthesis of proteins, structural and in some cases, as a catalytic molecule.

Chromosomes are composed of two types of large organic molecules called **proteins** and **nucleic acids**. You have also studied in class XI that nucleic acids are polymers of nucleotides. As you know nucleic acids are of two types — **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**.

THE DNA — Deoxyribonucleic Acid

DNA or deoxyribonucleic acid is not only the **largest macromolecule** but also represents genetic material of organism and molecular basis of heredity.

Discovery

(i) Nucleic acids were first isolated in 1869 by **Friedrich Miescher** from the nuclei of pus cells (white blood corpuscles – leucocytes). He named them **nuclein**.

(ii) In 1884, **Hertwig** proposed that nuclein was responsible for the transmission of hereditary traits.

(iii) **Altmann** (1889), a student of Miescher, renamed nuclein as nucleic acid because of its acidic properties. He also discovered the existence of two types of nucleic acids.

(iv) **Kornberg** was the first to synthesize DNA *in vitro* in 1957. Kornberg shared the 1959 Nobel Prize with Severo Ochoa for artificial synthesis of DNA and RNA.

Occurrence

In **prokaryotic cells**, DNA is circular and embedded in the cytoplasm and is often called **nucleoid**. It is not bounded by a nuclear membrane and is without histone proteins. It is termed as **naked DNA**. Many prokaryotes also possess extrachromosomal small circular DNA segments called **plasmids**.

In **eukaryotic cells**, DNA is linear and mainly confined to the nucleus as the component of chromosomes. It is called **nuclear DNA**. Nuclear DNA is associated with histone proteins to form chromatin fibres. Chromosomes are condensed chromatin fibres. A small quantity of DNA is also present in the mitochondria and plastids which is termed as **extranuclear** or **organeller DNA**. It is circular like prokaryotic DNA.

DNA is also present in some viruses.

Quantity of DNA

The DNA content is mostly constant in all the cells of a species. However, the DNA amount is doubled just before cell division. The gametes have half the amount of DNA as they possess half the number of chromosomes.

Length of DNA

DNA is a long polymer of deoxyribonucleotides. The length of DNA is usually defined as number of nucleotides or a pair of nucleotide referred to as base pairs (bp) present in it. Length of DNA is a characteristic of an organism. For example,

- (i) Bacteriophage $\phi \times 174$ has 5386 nucleotides
- (ii) Bacteriophage lambda has 48502 base pairs (bp)
- (iii) *Escherichia coli* has 4.6×10^6 bp
- (iv) Haploid content of human DNA is 3.3×10^9 bp

Structure of polynucleotide chain. Let us discuss the chemical structure of a polynucleotide chain (DNA or RNA).

A nucleotide is composed of three components —

1. A **phosphate group**,
2. A five carbon sugar (or **pentose**). In DNA, the sugar is 2-deoxyribose (thus the name deoxyribonucleic acid); in RNA, the sugar is ribose (thus ribonucleic acid) and
3. A heterocyclic nitrogen-containing compound called a **nitrogenous base**.

There are two types of nitrogenous bases.

(i) **Purines** — double-ring structure with N at position 1, 3, 7 and 9, e.g., adenine (A) and guanine (G).

(ii) **Pyrimidines** — 6-membered single-ring structure with N at 1 and 3 position, e.g., cytosine (C), thymine (T) and uracil (U). Cytosine is common in both DNA and RNA; thymine is present in DNA and uracil is present in RNA at the place of thymine.

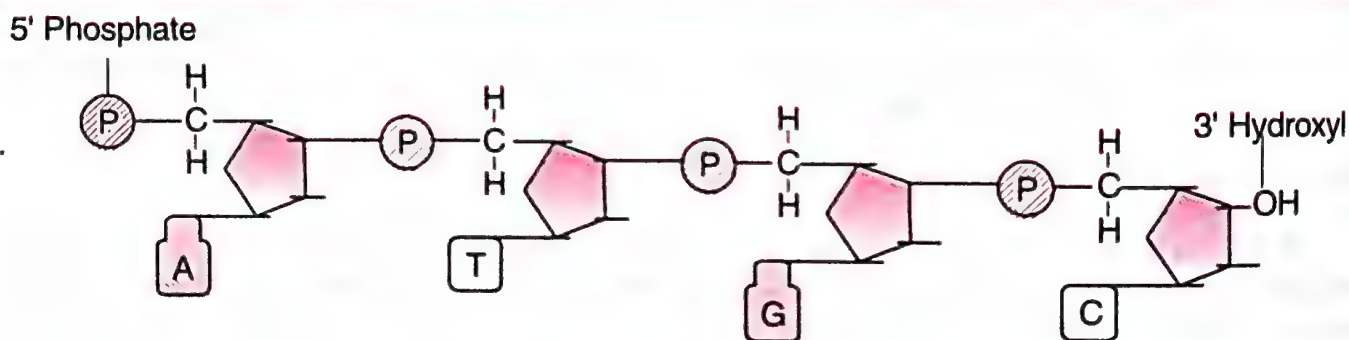


Fig. 6.1. A single stranded polynucleotide chain.

A polynucleotide chain shows following types of **bond** or **linkage** in its components :

(i) **Glycosidic bond** (N-glycosidic linkage). A linkage between a nitrogenous base and a pentose sugar to form a nucleoside is called **glycosidic bond**.

Nucleosides of DNA are deoxyadenosine, deoxyguanosine, deoxycytidine and deoxythymidine. Similarly, nucleosides of RNA are adenosine, guanosine, cytidine and uridine.

Purine nucleosides have 1'–9 glycosidic linkage (carbon 1' of sugar and 9 position of A/G). Pyrimidine nucleosides have 1'–1 linkage (carbon 1' of sugar and 1 position of T/C).

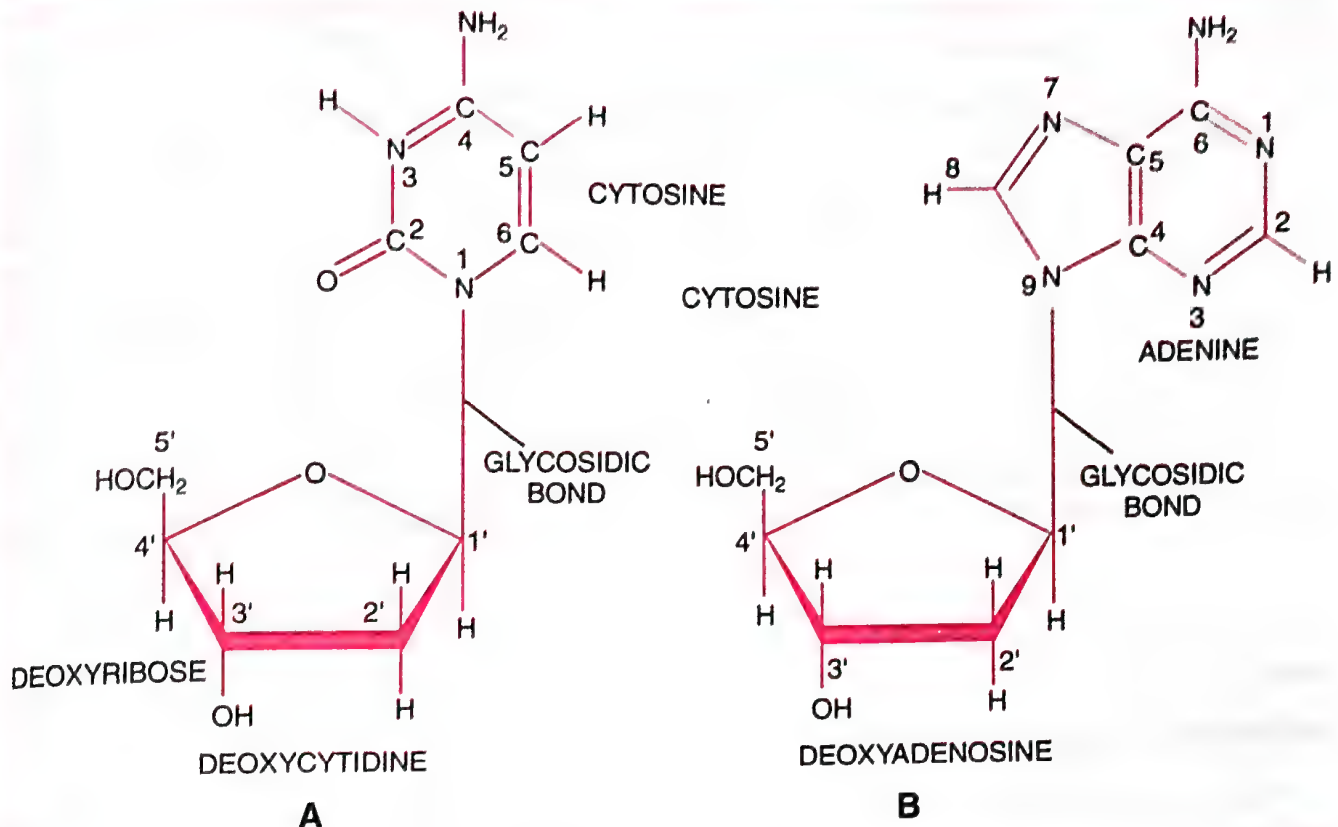


Fig. 6.2. Glycosidic bond in nucleosides. A, Linkage of a nitrogenous base cytosine to C-1 of deoxyribose. B, Linkage of nitrogenous base adenine with C-1 of deoxyribose.

(ii) **Phosphodiester Bond** (3'-5' phosphodiester linkage). Adjacent nucleotides are connected together to form a long polymer chain. For any one nucleotide, the phosphate attached to the hydroxyl* group at the 5' carbon of pentose sugar is in turn bonded to the hydroxyl group of the 3' carbon of the pentose sugar of the next nucleotide. Since each phosphate-hydroxyl bond is an ester bond, the linkage between two nucleotides is called **3'-5' phosphodiester linkage or bond**.

Both glycosidic and phosphodiester bonds are formed by condensation reactions that involve elimination of water.

Several thousands nucleotides are linked together to form a **polynucleotide chain**.

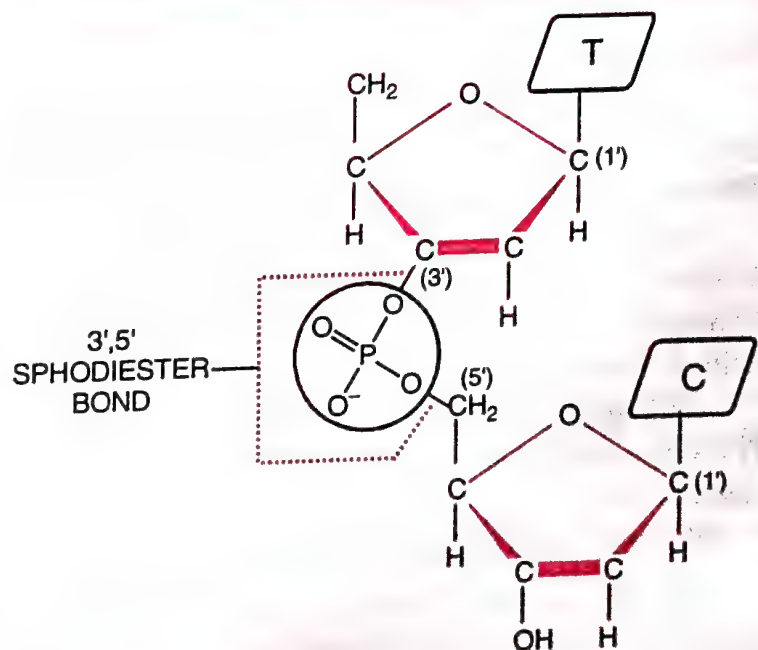


Fig. 6.3. Phosphodiester bond.

*Hydroxyl group. The group -OH in a chemical compound.

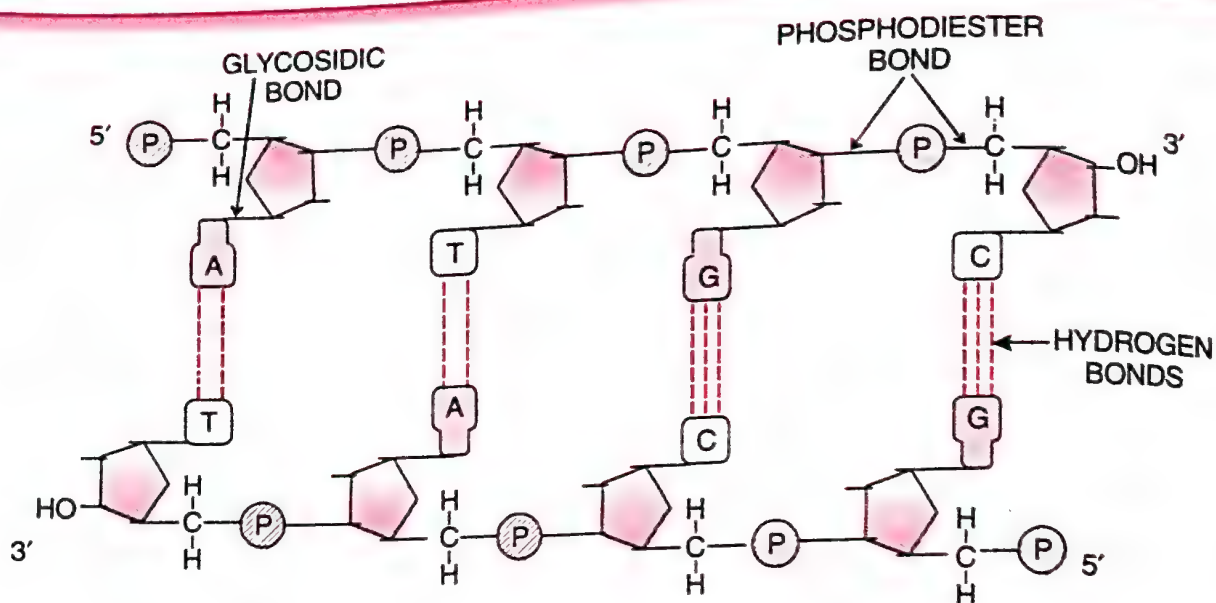


Fig. 6.4. A double stranded polynucleotide chain.

Polarity of Polynucleotide Chain

The polynucleotide chain shows polarity (direction). A polymer thus formed has at one end a free phosphate moiety (a part of a large molecule or structure) at 5' end of sugar which is referred to as 5' end of polynucleotide chain. Similarly, at the other end of the polymer the sugar has a free 3'-OH group which is referred to as 3'-end of the polynucleotide chain. The backbone in a polynucleotide chain is formed due to sugar and phosphates. The nitrogenous bases linked to sugar moiety project from the backbone.

In RNA, every nucleotide residue has an additional -OH group present at 2'-position in the ribose. Also, in RNA the uracil is present at the place of thymine (5-methyl uracil).

Structure of DNA

From 1950 to 1953 significant knowledge about structure of nucleic acid molecules was gained from the researches of **Erwin Chargaff**, **Maurice Wilkins**, **Rosalind Franklin**, **James Watson**, **Francis Crick** and others.

The correct structure of DNA was first worked out by James Watson and Francis Crick in 1953. Their **double-helix** model of DNA structure was based on two major investigations. Chargaff's rules for base pairing and the study of X-ray diffraction pattern of DNA which helped Watson and Crick to design the 3-dimensional structure of DNA.

Chargaff's Rules. Erwin Chargaff (1950) formulated important generalizations about DNA structure. These generalizations are called **Chargaff's rules**. These rules are summarized below.

- The purines and pyrimidines are always in equal amounts, *i.e.*, $A + G = T + C$.
- The amount of adenine is always equal to that of thymine and the amount of guanine is always equal to that of cytosine, *i.e.*, $A = T$ and $G = C$.
- The base ratio $A + T$ is constant for a species but may vary from one species to another. This ratio can be used to identify the species.

X-ray diffraction pattern of DNA. A technique for determining the three-dimensional structure of a large molecule is called **X-ray crystallography**. The pattern obtained after the

diffraction of X-ray through a crystal is termed as **X-ray diffraction pattern**.

In 1953, Maurice Wilkins and Rosalind Franklin took X-ray diffraction pictures of crystalline DNA. They concluded that DNA is a long molecule consisting of two similar strands running in parallel and helical manner where successive nucleotides occur at intervals of 0.34 nm (3.4 Å). They found DNA to have a diameter of 2 nm (20Å), major and minor grooves, a regular helix with 3.4 nm (34Å) distance and 10 pairs of nucleotides in each turn of spiral.

Watson and Crick Model of DNA. The above investigations helped Watson and Crick to design a model of DNA molecule in 1953.

Watson and Crick along with Wilkins received Nobel Prize (Medicine or Physiology) in 1962 for double helical model of DNA and significance for information transfer in living material.

Watson and Crick model of DNA has the following important features.

1. **Two Polynucleotide Chains or Strands.** A DNA molecule is formed of two long polynucleoid chains formed of **deoxyribonucleotides**. Each deoxyribonucleotide of DNA is formed by cross-linking of three chemicals — phosphoric acid (H_3PO_4), deoxyribose sugar ($\text{C}_5\text{H}_{10}\text{O}_4$) and a nitrogenous base. Four types of nitrogenous bases occur in DNA. They belong to two groups, **purines** (9-membered double rings with nitrogen at 1, 3, 7 and 9 positions) and **pyrimidines** (six membered rings with nitrogen at 1 and 3 positions). DNA has two types of purines (**adenine** or A and **guanine** or G) and two types of pyrimidines (**cytosine** or C and **thymine** or T). Depending upon the type of nitrogen base, DNA has four kinds of deoxyribonucleotides — deoxyadenosine 5-monophosphate (d AMP), deoxy guanosine 5-monophosphate (d GMP), deoxy thymidine 5-monophosphate (d TMP) and deoxy cytidine 5-monophosphate (d CMP).

2. **Glycosidic and Phosphodiester Bonds.** Nitrogen bases are attached to carbon 1' of deoxyribose sugar through a **glycosidic bond** by either their N-1 (in case of pyrimidine, cytosine or thymine) or N-9 (in case of purine, adenine or guanine) regions. The bond between two adjacent nucleotides of two adjacent sugar molecules at 3' and 5' positions with phosphate group is called **phosphodiester bond** (two ester formations by same phosphate radical).

Both types of bonds are formed by condensation reactions that involve elimination of water.

3. **DNA duplex.** As mentioned above a DNA molecule has two polynucleoid chains or strands. They are spirally coiled. The two spiral strands of DNA are collectively called **DNA duplex** (Fig. 6.6). DNA duplex has a diameter of 20Å. The two strands are not coiled upon each other but the whole double strand (DNA duplex) is coiled upon itself around a common axis in a right handed manner just as a rope stair is twisted to form a spiral. Thus, the coiling becomes **plectonemic**, i.e., the two strands cannot be separated without completely unwinding them.

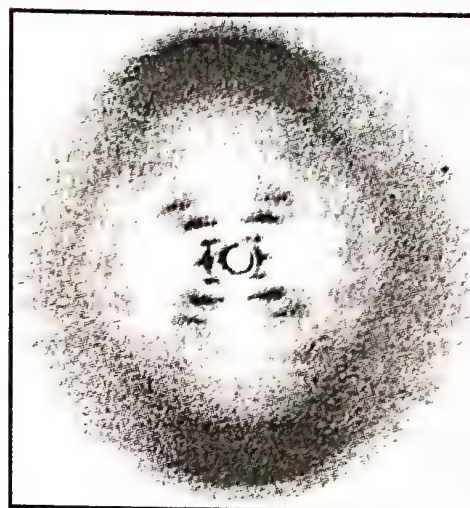


Fig. 6.5. An X-ray diffraction photograph of DNA that led to the double helix model of DNA structure. The heavy dark patterns (top and bottom) indicate that the bases are stacked perpendicular to the axis of the molecule with a periodicity of 3.4 Å.

Due to spiral twisting, the DNA duplex comes to have two types of alternate grooves, major (length 22\AA) and minor (length 12\AA). The type of DNA described here is the B form. One turn of the spiral has a distance of 34\AA . This length contains 10 deoxyribonucleotides in each chain so that the average distance between adjacent deoxyribonucleotide is 3.4\AA .

4. **Backbone of DNA Strand.** Deoxyribose sugar and phosphoric acid form the **back-bone of DNA** strand while nitrogen base lies at right angle to it. The back-bone is formed of alternate deoxyribose sugar and phosphoric acid groups. The nitrogen bases project at right angles to this back-bone from the region of sugar residues.

5. **Polarity.** The polynucleotide chains show polarity (direction). One end of each DNA strand has a free phosphate moiety (a part of a large molecule or structure) at 5' end of sugar which is called **5' end** of DNA strand. The other end of the strand, the sugar has a free 3'-OH group which is termed **3'-end**. The nitrogenous bases linked to sugar moiety project from the backbone.

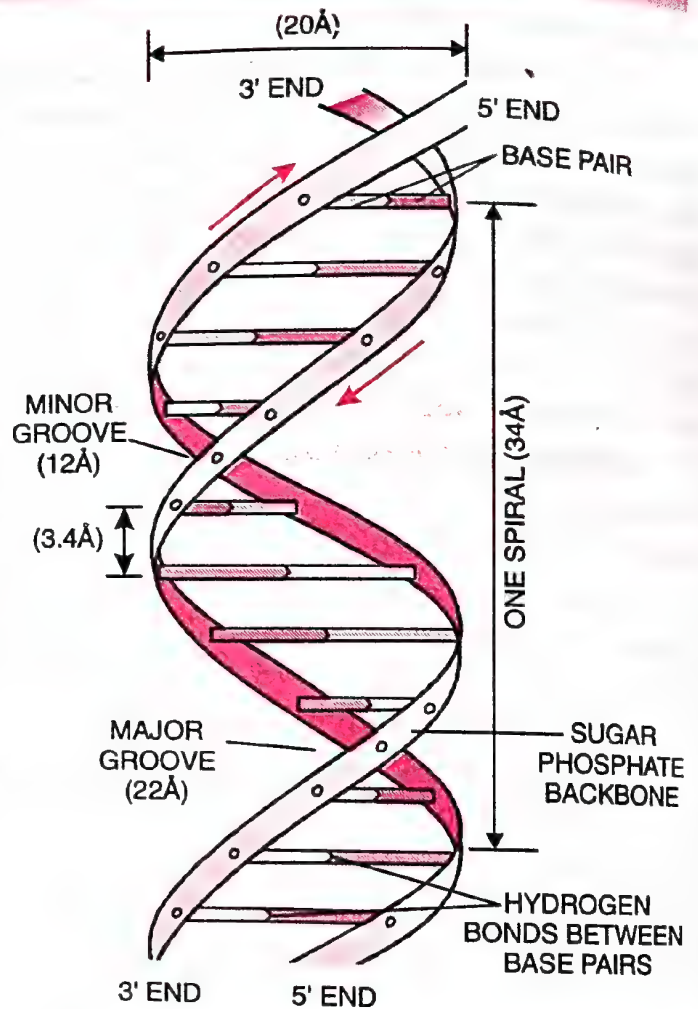


Fig. 6.6. Double helix structure of DNA as proposed by Watson and Crick (1953).

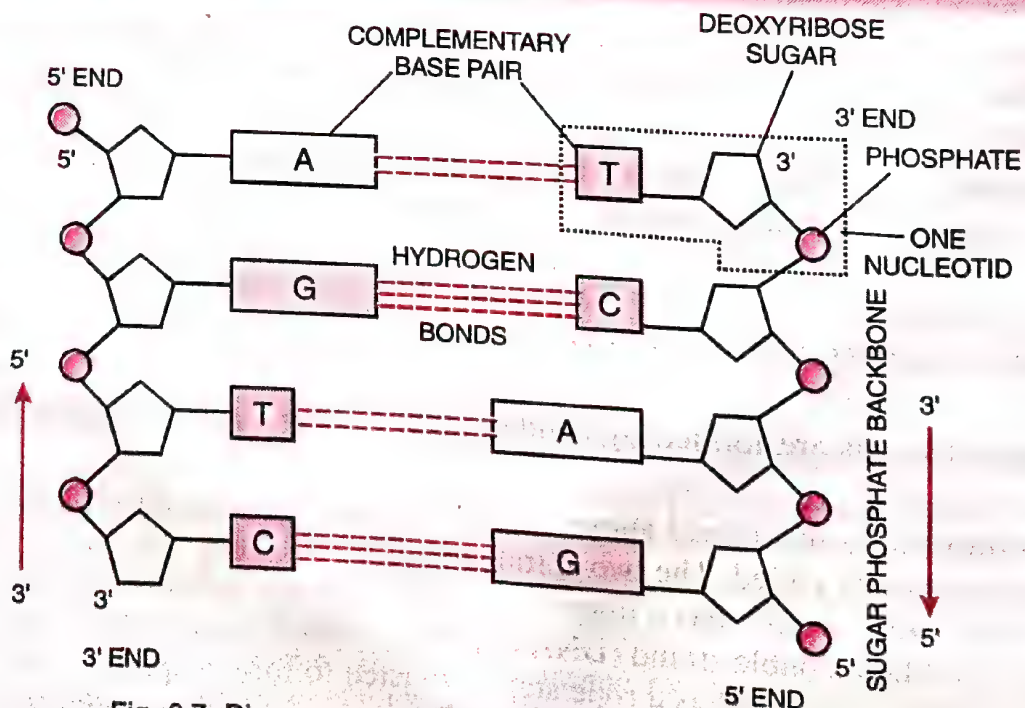


Fig. 6.7. Diagrammatic representation of the two DNA strands.

6. **Complementary Base Pairing.** Base pairing is the pairing formed in DNA double helix between purine of one strand and pyrimidine of the second strand. Purines found in DNA are adenine (A) and guanine (G). Pyrimidines of DNA are thymine (T) and cytosine (C). Adenine of one strand always pairs with thymine of the other pair, *i.e.*, A + T and guanine of one strand always pairs with cytosine, *i.e.*, G + C. The amount of adenine is always equal to that thymine and amount of guanine is always equal to that of cytosine, *i.e.*, A = T and G = C. This finding confirmed Chargaff's rule.

As was proved by the specific purine-pyrimidine (A + T and G + C) base pairing the two strands are always **complementary** (not identical) to each other.

The way in which the bases form pairs between the two DNA strands is known as **complementary base pairing**.

7. **Hydrogen Bonds.** The two strands of DNA are held together by hydrogen bonds between their bases. Two hydrogen bonds occur between adenine and thymine [A = T]. There are three hydrogen bonds between guanine and cytosine (G = C). G = C bonds are stronger than A = T bonds.

8. **Antiparallel strands.** The two strands of DNA duplex are parallel but are oriented in opposite directions. Such strands are called **antiparallel**. The antiparallel strands form a right-handed helix. The 5' end of one strand lies opposite 3' end of the other. One strand is oriented in the 5' → 3' direction and the other strand in the 3' → 5' direction. This arrangement is useful in complementary base pairing and replication of DNA.

Salient Features of the Double-helix Structure of DNA

1. DNA has two polynucleotide chains.
2. The two chains of DNA have *antiparallel polarity*, 5' → 3' in one and 3' → 5' in other.
3. Backbone of each polynucleotide chain is made of alternate sugar-phosphate groups. The nitrogen bases project inwardly.
4. Nitrogen bases of two polynucleotide chains form complementary pairs, A opposite T and G opposite C.
5. A large sized purine always comes opposite a small sized pyrimidine. This generates uniform distance between two strands of helix.
6. Adenine (A) of one polynucleotide chain is held to thymine (T) of opposite chain by two hydrogen bonds. Guanine (G) of one chain is similarly held to cytosine (C) of the other chain by three hydrogen bonds.
7. The double chain is coiled in a helical fashion. The coiling is right handed. This coiling produces minor and major grooves alternately.
8. The pitch of helix is 3.4 nm (34 Å) with roughly 10 base pairs in each turn. The average distance between two adjacent base pairs comes to about 0.34 nm (0.34×10^{-9} m or 3.4 Å).
9. Planes of adjacent base pairs are stacked over one another. Alongwith hydrogen bonding, the stacking confers stability to the helical structure.

Comparison of structure of Purine and Pyrimidine

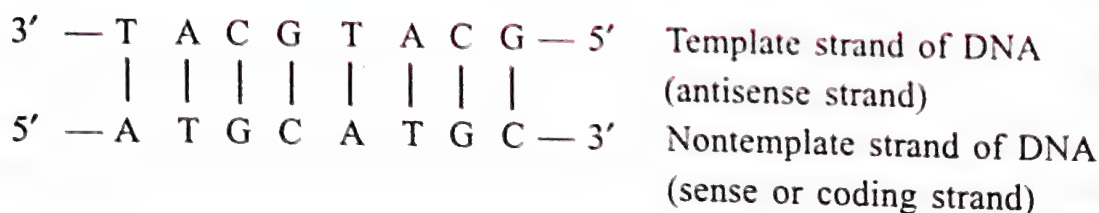
<i>Purine</i>	<i>Pyrimidine</i>
<ol style="list-style-type: none"> 1. Purines are larger-sized nitrogen containing biomolecules. 2. A purine is nine-membered. 3. It is a double ring. 4. A purine contains four nitrogen atoms at 1, 3, 7 and 9 positions. 5. Purine bases are of two types, adenine (A) and guanine (G). 	<ol style="list-style-type: none"> 1. Pyrimidines are smaller-sized nitrogen containing biomolecules. 2. A pyrimidine is 6-membered. 3. It is a single ring. 4. A pyrimidine has nitrogen atoms at two places, 1 and 3 positions. 5. Pyrimidine bases are of three types— cytosine (C), thymine (T) and uracil (U).

• Why the distance between two polynucleotide chains in DNA remains almost constant ?

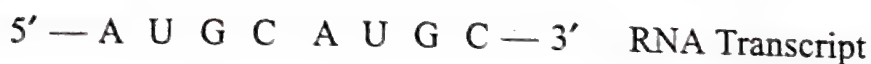
Two types of forces stabilise the duplex and hold the two DNA chains together : (i) Hydrogen bonds between the complementary nitrogen bases of the two chains. (ii) Hydrophobic interactions between nitrogen bases. The latter also kept stacked inside the helix while the polar groups are kept on the outside in contact with water. (iii) Base pairing between purines and pyrimidines.

Sense and Antisense Strands of DNA. Out of the two strands of DNA duplex, only one stores the genetic information and acts as template for the transcription of mRNA. This strand is called **template strand** or **antisense strand**. This strand has 3' → 5' polarity. Its complementary strand is termed as **nontemplate strand** (sense or **coding strand**). This strand has 5' → 3' pority.

DNA



mRNA



mRNA is transcribed on template/antisense strand of DNA.

Fig. 6.8. Two strands of DNA and an RNA transcript.

Differences between Template/Antisense Strand and Coding/Sense Strand

<i>Template/Antisense Strand</i>	<i>Coding/ Sense Strand</i>
<ol style="list-style-type: none"> 1. It has 3' → 5' polarity. 2. It takes part in transcription. 3. It is that strand upon which RNA is transcribed in 5 → 3 direction. 	<ol style="list-style-type: none"> 1. It has 5' → 3' polarity. 2. It has no role in transcription. 3. It has same sequence of bases found in mRNA except T at the place of U. It does not code any information.

Denaturation and Renaturation of DNA. Conversion of double stranded DNA to single stranded state usually by heating is called **DNA denaturation**. The denatured DNA is

When the denatured DNA is incubated at a low temperature, the two separated strands reassociate to form a DNA duplex. This process is termed **DNA renaturation**.

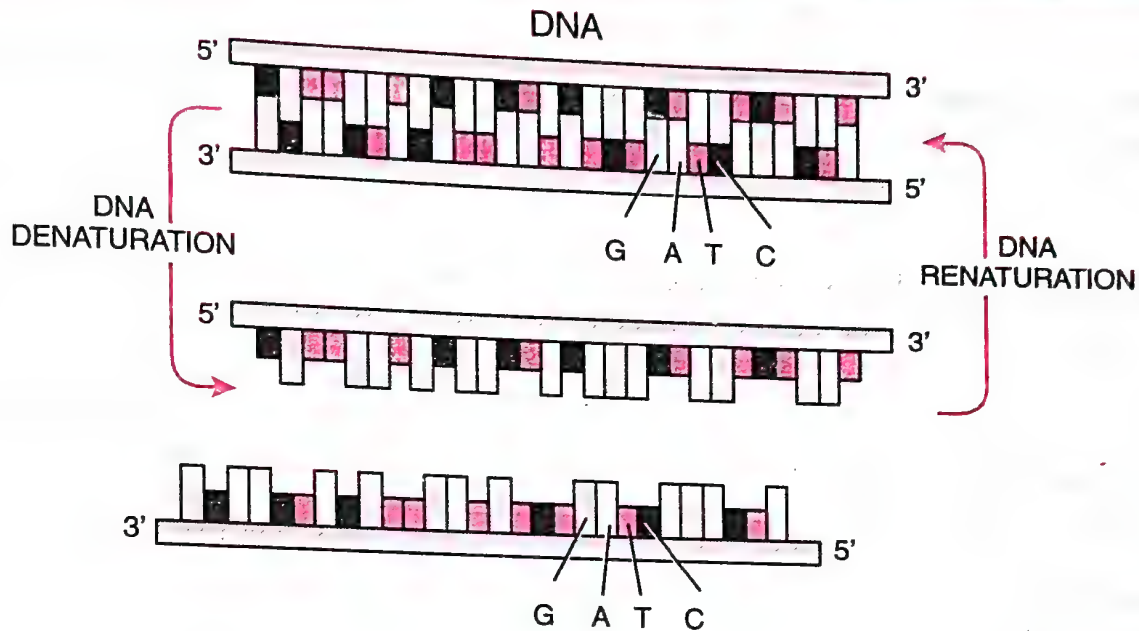


Fig. 6.9. Denaturation and Renaturation of DNA.

Hereditary Information. The arrangement of nitrogen bases of DNA (and its product mRNA) determines the sequence of amino acid groups in polypeptides or proteins formed over ribosomes. One amino acid is specified by the sequence of three adjacent nitrogen bases. The latter is called **codon**. The segment of DNA which determines the synthesis of complete polypeptide is known as **cistron**. In procaryotes, a cistron has a continuous coding sequence from beginning to end. In eucaryotes a cistron contains **noncoding regions** which do not produce part of gene product. They are called **introns**. Introns are often variable. The coding parts are known as **exons**. Cistrons having introns are called **split genes**.

Types of DNA

1. **Linear and Circular DNA.** **Linear DNA** is found in the nuclei of eukaryotic cells. It has free ends. It is associated with proteins. Linear DNA is organized into a number of chromosomes, each containing a long DNA double helix.

Circular DNA is found in prokaryotic cells and in the mitochondria and plastids of eukaryotic cells. Circular DNA has its ends jointed together. It is not associated with proteins. The prokaryotic DNA is as a single chromosome.

Both linear and circular DNA are coiled to be accommodated in a small space.

2. **Single Stranded and Double Stranded DNA.** **Single Stranded DNA** was first observed by Sinsheimer (1958) in the spherical bacteriophage, $\phi \times 174$. **Double Stranded DNA** consists of two antiparallel strands of deoxyribonucleotide units. It is found in almost all cells which possess DNA as genetic material except some viruses.

3. **Trophic and Genetic DNA.** The ciliates (e.g., *Paramecium*) have both trophic and genetic DNA in the macronucleus and micronucleus respectively. The macronucleus controls the vegetative functions and the micronucleus controls the reproductive function.

4. **A, B, C, D, E and Z Forms of DNA.**

A-DNA. Right handed helix with 11 base pairs per turn.

B-DNA. Watson and Crick model of DNA is B form of DNA. It is the most common form of DNA found in organisms. It is right handed helix with each turn of spiral having 10 base pairs.

C-DNA. Right handed helix with 9 base pairs per turn.

D-DNA. Right handed helix with 8 base pairs per turn.

E-DNA. Form adapted by synthetic DNA lacking guanine. There are $7\frac{1}{2}$ base pairs per turn.

Z-DNA. Left handed helix, with zigzag and 12 base like sugar-phosphate back bones and 12 base pairs per turn of helix.

Differences in different forms of DNA

	B	Z	A	C	D
1. Handedness of helix	Right handed	Left handed	Right handed	Right handed	Right handed
2. Pitch of helix per turn	34 Å	46 Å	25 Å	30 Å	24 Å
3. Diameter of helix	20 Å	18 Å (thinnest)	26 Å (widest)	19 Å	—
4. Stability	Stable and physiologically active form	Unstable	Unstable	Unstable	Unstable
5. Base pairs per turn of helix	10	12 (6 dimers)	11	9.33	8
6. Distance (vertical rise per base pair) between 2 base pairs	3.4 Å	3.8 Å	2.5 Å	3.3 Å	3.03 Å
7. Repeating unit	Mononucleotide	Dinucleotide	Mononucleotide	Mononucleotide	Mononucleotide

5. **Coding and Noncoding DNA.** Depending on the ability to form functional or non-functional products, DNA has two types of segments, coding and noncoding. In eukaryotes a greater part of DNA is noncoding since it does not form any functional product. They often possess repeated sequences or **repetitive DNA**. Most of them have fixed positions. Some can move from one place to another. The mobile sequences are called **jumping genes** or **transposons**. In prokaryotes the amount of noncoding or nonfunctional DNA is small. **Coding DNA** consists of coding DNA sequences. These are of 2 types — *protein coding sequences* coding for all proteins except histone and *nonprotein coding sequences* for tRNA, rRNA and histones.

Repetitive DNA. It is the part of DNA which contains the same sequence of nitrogen bases repeated more than once in genome. Repetitive DNA is common in eukaryotes.

Satellite DNA. Satellite DNA is highly repetitive DNA which forms a separate fraction

during ultracentrifugation. Satellite DNA is typically found in centromeres and heterochromatin, usually it does not transcribe and translate.

Depending upon the number of bp (base pairs) involved in repeat regions, satellite DNA is of further two types.

Microsatellite with a few (1-6) bp repeats.

Minisatellite with more (11-60) bp repeats. Minisatellite DNA is highly variable and is specific for each individual. It is used in DNA fingerprinting discovered by Jeffreys *et al* (1985).

Differences between Repetitive DNA and Satellite DNA

<i>Repetitive DNA</i>	<i>Satellite DNA</i>
<ol style="list-style-type: none"> 1. It is the part of DNA which contains the same sequence of nitrogen bases repeated more than once in genome. 2. It transcribes and translates. 3. The two types are not present in repetitive DNA. 	<ol style="list-style-type: none"> 1. It is highly repetitive DNA which forms a separate fraction during ultracentrifugation. 2. Usually it does not transcribe and translate. 3. It is of two types : microsatellite and minisatellite.

Palindromic DNA (Palindrome). It is a sequence of DNA base pairs which reads the same whether read from left to right or right to left. Palindromic DNA has similar sequence in both strands. For example, 5'-GAATTC-3' on one strand and 3'-CTTAAG-5' on the other strand. Palindromic sequences are recognized by restriction endonucleases.

DNA Polymorphism. DNA polymorphism refers to the variation at genetic level, where an inheritable mutation is observed in a population at high frequency. SNP, RFLP and VNTRs are good examples of DNA polymorphism.

Single Nucleotide Polymorphism (SNP). It is a type of DNA polymorphism consisting of small variations in DNA sequences, in which a single nucleotide pair is replaced by one or the other three pairs.

SNP (pronounced *snip* ; plural *snips*) is responsible for most of genetic variations in human beings. Their number is believed to be more than 10 million. Already more than 1.4 million of them have been discovered. SNPs would be useful in finding chromosomal locations for disease-associated sequences and tracing human evolutionary history.

SNP is used in genetic mapping.

Restriction Fragment Length Polymorphism (RFLP). It is a type of DNA polymorphism in which there is variation between individuals of a species in the banding pattern of DNA fragments generated when DNA samples from individuals are cleaved by a restriction endonuclease. In RFLP analysis, the DNA sample is broken into pieces by **restriction enzymes** and the resulting restriction fragments are separated according to their lengths by **gel electrophoresis**.

RFLP is also used in genetic mapping.

Variable Number Tandem Repeats (VNTRs). It is also a type of DNA polymorphism in which tandem repeats found at specific loci in the genome show variation in the number of repeating units between individuals of a population. VNTRs are used in DNA fingerprinting.

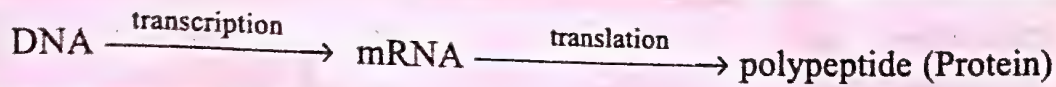
Differences between Prokaryotic DNA and Eukaryotic DNA	
Prokaryotic DNA	Eukaryotic DNA
<ol style="list-style-type: none"> 1. It is found in cytoplasm, mitochondria and plastids. 2. Much less in amount, less than 0.1 Pg. 3. It is usually circular, double stranded. 4. It is naked, without histone. 5. It can code for fewer proteins. 6. Noncoding introns are absent. 7. G : C contents are more than A : T. 8. Repeated sequences absent. 9. Very little part of DNA is functionless. 	<ol style="list-style-type: none"> 1. It is found in nucleus. 2. Much more (> 1 Pg) in amount than prokaryotic DNA. 3. It is usually linear, double stranded. 4. It is wrapped over histone. 5. It can code for far more proteins. 6. DNA is mosaic of exons (coding regions) and introns (noncoding region). 7. A : T contents are more than G : C. 8. Present. 9. Greater part of DNA is noncistronic and functionless.

Functions of DNA

1. **Genetic Information** (Genetic Blue Print). DNA is the genetic material which carries all the hereditary information. The genetic information is coded in the arrangement of its nitrogen bases.
2. **Replication**. DNA has unique property of replication or production of carbon copies (Autocatalytic function). This is essential for transfer of genetic information from one cell to its daughters and from one generation to the next.
3. **Chromosomes**. DNA occurs inside chromosomes. This is essential for equitable distribution of DNA during cell division.
4. **Recombinations**. During meiosis, crossing over gives rise to new combination of genes called recombinations.
5. **Mutations**. Changes in sequence of nitrogen bases due to addition, deletion or wrong replication give rise to mutations. Mutations are the fountain head of all variations and evolution.
6. **Transcription**. DNA gives rise to RNAs through the process of transcription. It is heterocatalytic activity of DNA.
7. **Cellular Metabolism**. It controls the metabolic reactions of the cells through the help of specific RNAs, synthesis of specific proteins, enzymes and hormones.
8. **Differentiation**. Due to differential functioning of some specific regions of DNA or genes, different parts of the organisms get differentiated in shape, size and functions.
9. **Development**. DNA controls development of an organism through working of an internal genetic clock with or without the help of extrinsic information.
10. **DNA Finger Printing**. Hypervariable microsatellite DNA sequences of each individual are distinct. They are used in identification of individuals and deciphering their relationships. The mechanism is called DNA finger printing.
11. **Gene Therapy**. Defective heredity can be rectified by incorporating correct genes in place of defective ones.
12. **Antisense Therapy**. Excess availability of anti-mRNA or antisense RNAs will not allow the pathogenic genes to express themselves. By this technique failure of angioplasty has been checked. A modification of this technique is **RNA interference (RNAi)**.

Central Dogma of Molecular Biology

It is the flow of information from DNA to mRNA (transcription) and then decoding the information present in mRNA in the formation of polypeptide chain or protein (translation).



In other words the four letter language of DNA is transcribed into four letter language of mRNA which is then translated into 20 letter language of protein.

The concept of central dogma of molecular biology was proposed by Crick in 1958. It proposes **unidirectional flow of information** from DNA to RNA and then to protein. Com-moner (1968) propounded a **circular flow of information** (from DNA → RNA → Protein → RNA → DNA).

Temin (1970) and Baltimore (1970) reported that **double stranded RNA of Rous Sarcoma Virus (RSV)** operates a **central dogma reverse** (inverse flow of information). RNA of these viruses first synthesises DNA through **reverse transcription** or **teminism**. DNA then transfers information to RNA which takes part in translation of coded information to form polypeptide (Fig 6.10C). The mechanism is characteristic of retroviruses, e.g., HIV.

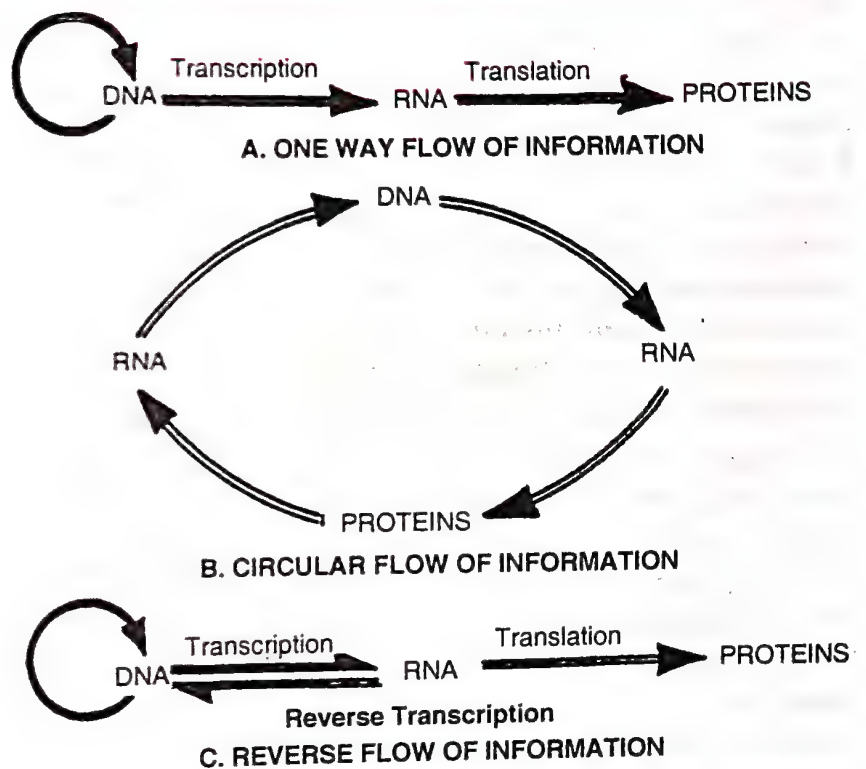


Fig. 6.10. Diagrammatic representation of three concepts about the flow of transcriptional information from DNA.

Packaging of DNA Helix

The average distance between the two adjacent base pairs is 0.34nm ($0.34 \times 10^{-9}\text{m}$ or 3.4 Å). The number of base pairs in *Escherichia coli* is 4.6×10^6 . The total length of its DNA is 1.36 mm. Similarly 6.6×10^9 bp of the two human genomes or any other typical mammalian cell, i.e., diploid cell will have DNA length of 2.2 metres. The long sized DNA are accommodated in small areas (about 1 µm in *E. coli* and 5 µm nucleus in human beings) only through packing or compaction. DNA is acidic due to presence of a large number of only through packing or compaction. DNA is acidic due to presence of a large number of phosphates groups. Compaction occurs by folding and attachment of DNA with basic proteins, nonhistone in prokaryotes and histones in eukaryotes.

If the length of *E. coli* DNA is 1.36 mm can you calculate the number of base pairs in *E. coli* ?

DNA Packaging in Prokaryotes. In prokaryotes, such as *E. coli* though they do not have a defined nucleus, the DNA is not scattered throughout the cell. DNA (being negatively charged) is held with some **nucleoid-associated proteins (NAPs)**, that have positive charges) in a region termed as '**nucleoid**'. The DNA in nucleoid is organised in large loops held by proteins.

DNA Packaging in Eukaryotes. In eukaryotes, DNA packaging is carried out with the help of positively charged basic proteins called **histones**. Histones are rich in basic amino acid residues, **lysines** and **arginines**. Both the amino acid residues carry positive charges on their side chains. Histones and DNA organised to form **nucleosome**. Small segment of DNA connecting two adjacent nucleosomes is called **interbead** or **linker DNA**. Nucleosome and linker DNA together constitute **chromatosome**. Nucleosome chain gives a **beads on string** appearance under electron microscope.

Types of histones. There are five types of histone proteins — H_1 , H_2A , H_2B , H_3 and H_4 . Four of them (H_2A , H_2B , H_3 and H_4) occur in pairs to produce **histone octamer**, called **nucleosome core** or **core of nucleosome**. DNA of about 200 bp makes 1.75 left handed turns over the histone octamer to form a nucleosome. A fifth type of histone called H_1 is attached over the linker DNA.

Histone-DNA Interactions. Histone contains a large proportion of the positively charged (basic) amino acids, lysine and arginine in their structure. DNA is negatively charged due to the phosphate groups on its backbone. The result of these opposite charges is strong attraction and therefore, high binding affinity between histones and DNA. Hydrogen bonding between amino acids in the histone peptide and the phosphodiester backbone of DNA are also important in further stabilizing the structure.

Solenoid Model of Folding. The beaded string is coiled to form cylindrical coil or **solenoid** having 6 nucleosomes per turn. Actually the nucleosomal organisation has approximately 10 nm thickness, which gets further condensed and coiled to produce a solenoid of 30 nm diameter. This solenoid structure undergoes further coiling to produce a chromatin fibre of 300 nm diameter and then a chromatid of 700 nm diameter and ultimately metaphase chromosome of 1400 nm diameter.

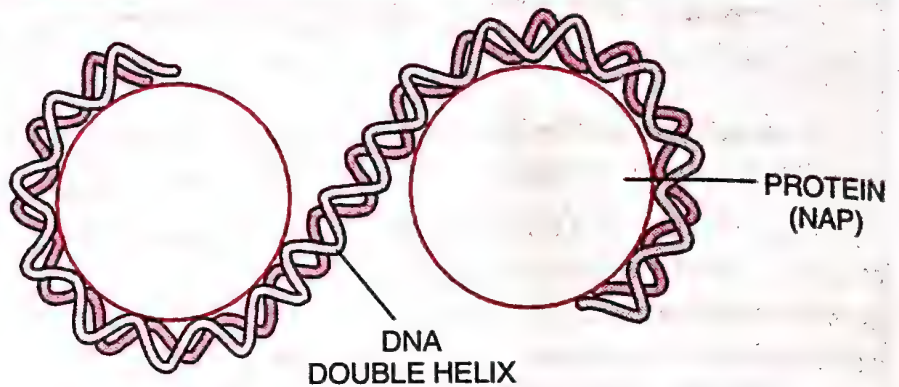


Fig. 6.11. DNA packaging in *E. coli*.

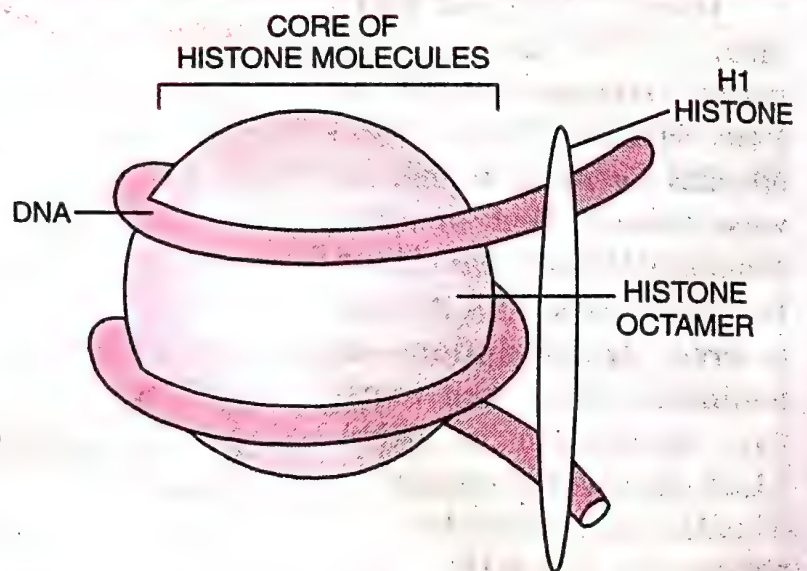


Fig. 6.12. Nucleosome.

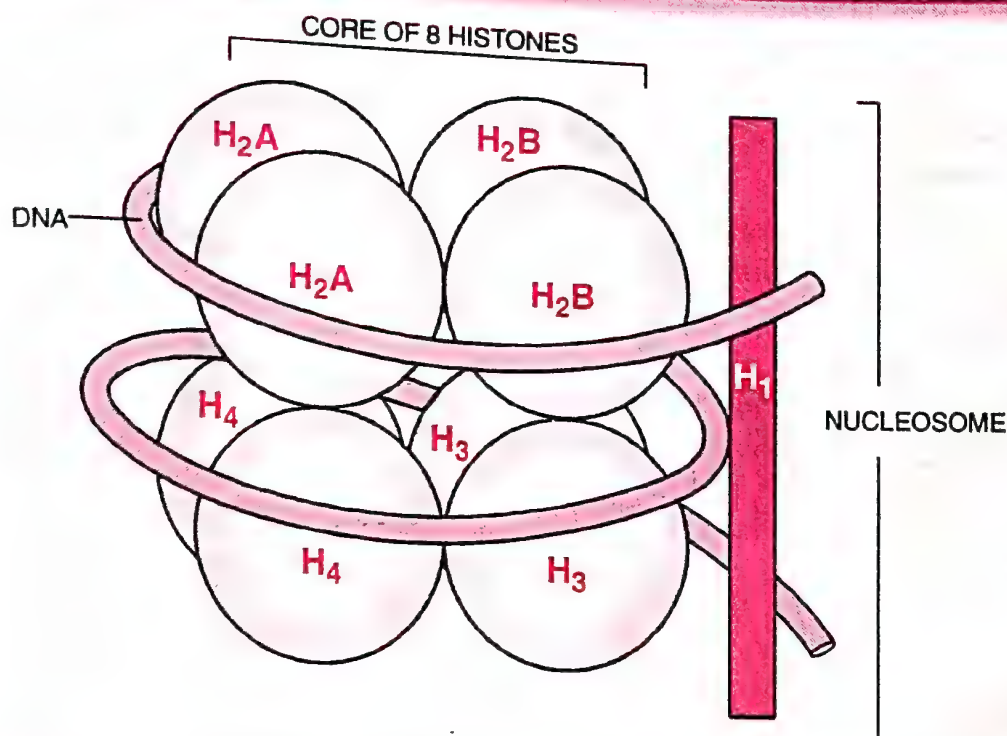


Fig. 6.13. Nucleosome showing different histones.

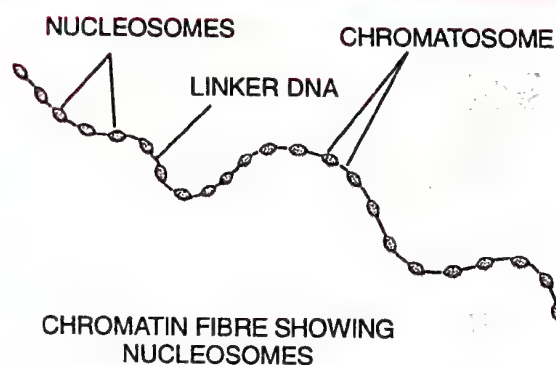
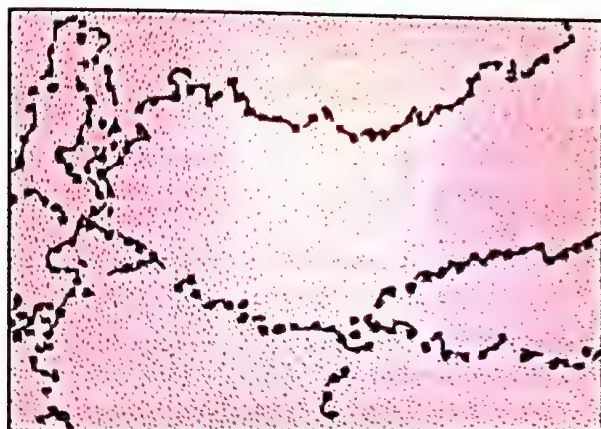


Fig. 6.14. EM picture - 'Beads-on-String'

Non-histone Chromosomal (NHC) Proteins. The packaging of chromatin at higher level requires additional set of proteins that collectively are referred to as **non-histone chromosomal (NHC) proteins**. On the basis of staining behaviour in a typical nucleus, chromatin is of two types : euchromatin and heterochromatin.

Differences between Euchromatin and Heterochromatin

Euchromatin	Heterochromatin
<ol style="list-style-type: none"> 1. It stains lightly. 2. This chromatin is loosely packed. 3. It is transcriptionally active. 4. Replication takes place at early S-phase as it takes less time to unwind. 	<ol style="list-style-type: none"> 1. It stains darkly. 2. This chromatin is more densely packed. 3. It is transcriptionally inactive. 4. Replication takes place at late S-phase as it takes longer time to unwind.

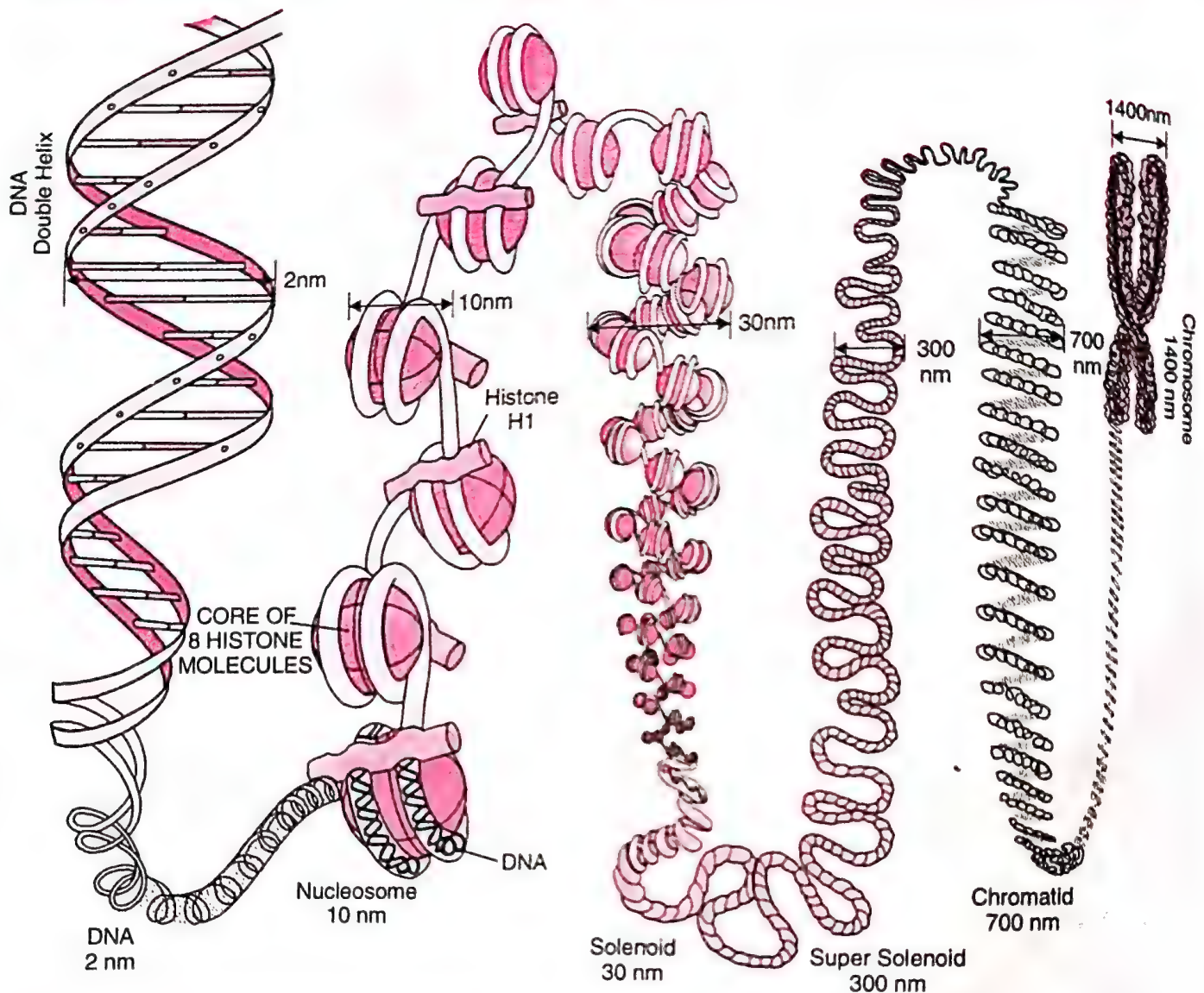


Fig. 6.8. Various steps in the folding and super folding of the basic chromatin components to generate an eukaryotic chromosome.

Theoretically how many such beads (nucleosomes) do you imagine are present in a mammalian cell ?

200 bp are present in = 1 bead (typically)

$$6.6 \times 10^9 \text{ bp are present in} = \frac{1}{200} \times 6.6 \times 10^9$$

$$= 3.3 \times 10^7 \text{ beads}$$

Theoretically, approx. = 3.3×10^7 beads are present in a mammalian cell.

THE SEARCH FOR GENETIC MATERIAL

Mendel proposed the principles of inheritance in 1866. Meischer discovered nuclein in 1869. Sutton and Boveri proposed chromosome theory of inheritance in 1902 indicating that genetic material is contained in chromosomes. In 1933 Morgan confirmed the findings of Sutton and Boveri. He proved that genes are located in the chromosomes present inside the

nucleus of most cells. But the question of what molecule was actually the genetic material, had not been answered.

Transforming Principle

The transforming principle was an early name for the genetic material (DNA). In 1928 scientists did not know yet that DNA carried genetic information, but they knew that there was something that could cause bacteria to transform from one type to another and they called it the transforming principle.

Griffith's Experiment. The transformation experiments, conducted by Frederick Griffith in 1928, are of great evidence in establishing the nature of genetic material. He performed series of experiments by selecting two strains of bacterium *Streptococcus pneumoniae* (= *Diplococcus pneumoniae*) namely, S-III strain and R-II strain.

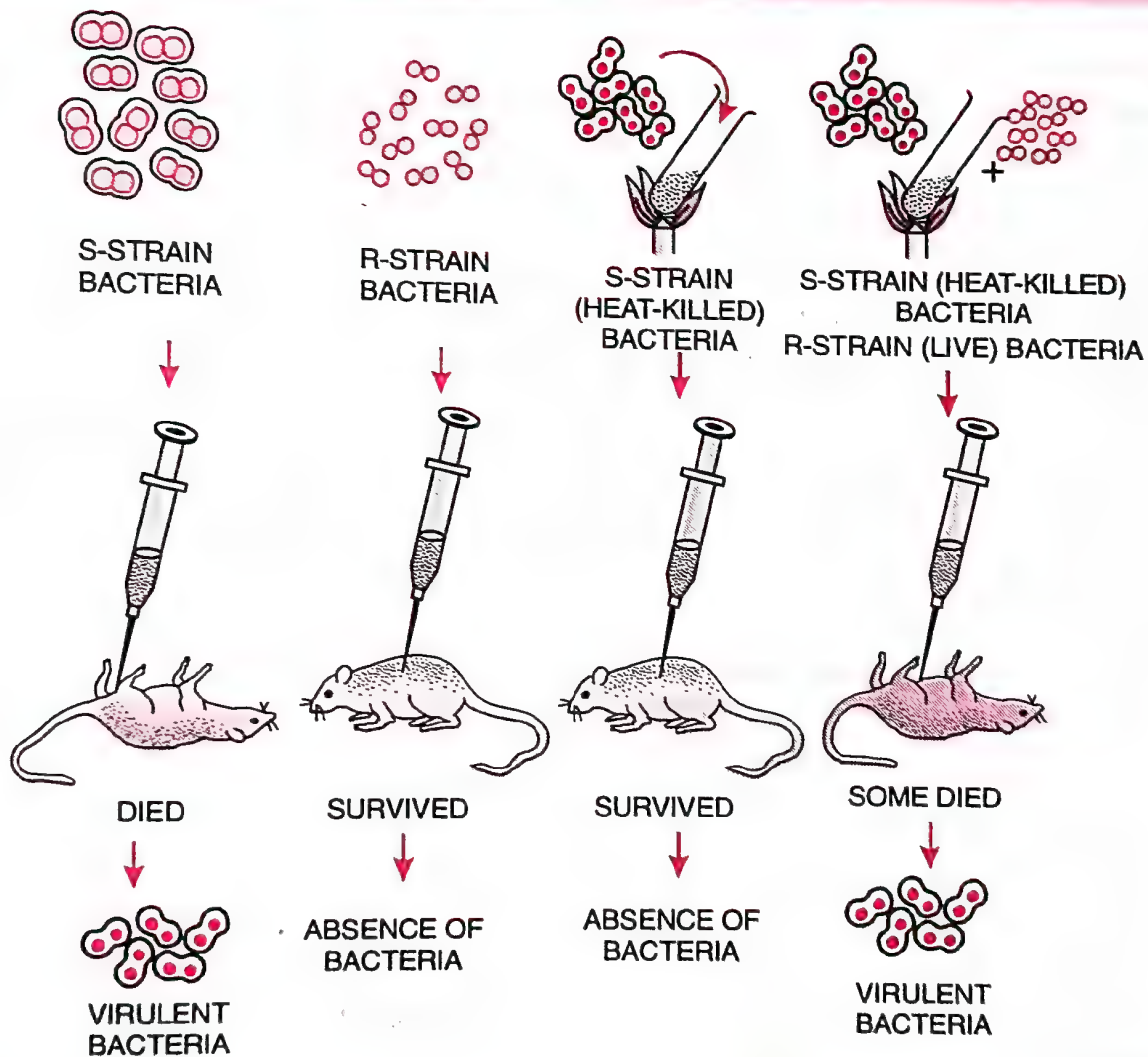


Fig. 6.16. Summary of Griffith's experiments on transformation in *Diplococcus* or *Streptococcus pneumoniae* (= *Diplococcus pneumoniae*).

(i) S-III strain/smooth or capsulated type has a mucous (polysaccharide) coat and produce smooth shiny colonies in culture plate. These are **virulent** and cause pneumonia.

(ii) R-II strain/rough or non-capsulated type has no mucous coat and produce rough colonies. These are **non-virulent** and do not cause pneumonia.

The experiment can be described in the following four steps :

- (a) S strain bacteria (live) → Injected into mice → Mice died
- (b) R strain bacteria (live) → Injected into mice → Mice survived
- (c) S strain (heat-killed) bacteria → Injected into mice → Mice survived
- (d) S strain (heat-killed) bacteria + R-strain (live) bacteria → Injected into mice → Some died

Griffith was able to kill bacteria by heating them. He observed that heat-killed S-strain bacteria injected into mice did not kill them. When he injected a mixture of heat-killed S and live R-bacteria, the mice died. Moreover, he recovered living S-bacteria from the dead mice.

Griffith concluded that the R-strain bacteria had somehow been **transformed** by the heat-killed S-strain bacteria. This occurred perhaps due to absorption of some transforming principle or substance by rough type bacteria from heat-killed smooth bacteria. It had enabled the R-strain to synthesize a smooth polysaccharide coat and become virulent. This must be due to the transfer of the genetic material. However, the biochemical nature of genetic material was not defined from his experiments.

Biochemical Characterisation of Transforming Principle. Prior to the work of Oswald Avery, Colin MacLeod and Maclyn McCarty (1933-44), the genetic material (transforming principle) was thought to be a protein. These three scientists worked to determine the biochemical nature of 'transforming principle'.

Experiment conducted by Avery, MacLeod and McCarty. They purified biochemicals, *i.e.*, proteins, DNA and RNA from the heat-killed S-cells to see which ones could transform live R-cells into S-cells. They discovered that DNA alone from S-bacteria caused R-bacteria to become transformed.

They also discovered that protein-digesting enzymes (proteases) and RNA-digesting enzymes (RNases) did not affect transformation, so the transforming substance was not a protein or RNA. Digestion with DNase did inhibit transformation, suggesting that the DNA caused the transformation. They concluded that DNA is the hereditary material, but not all biologists were convinced.

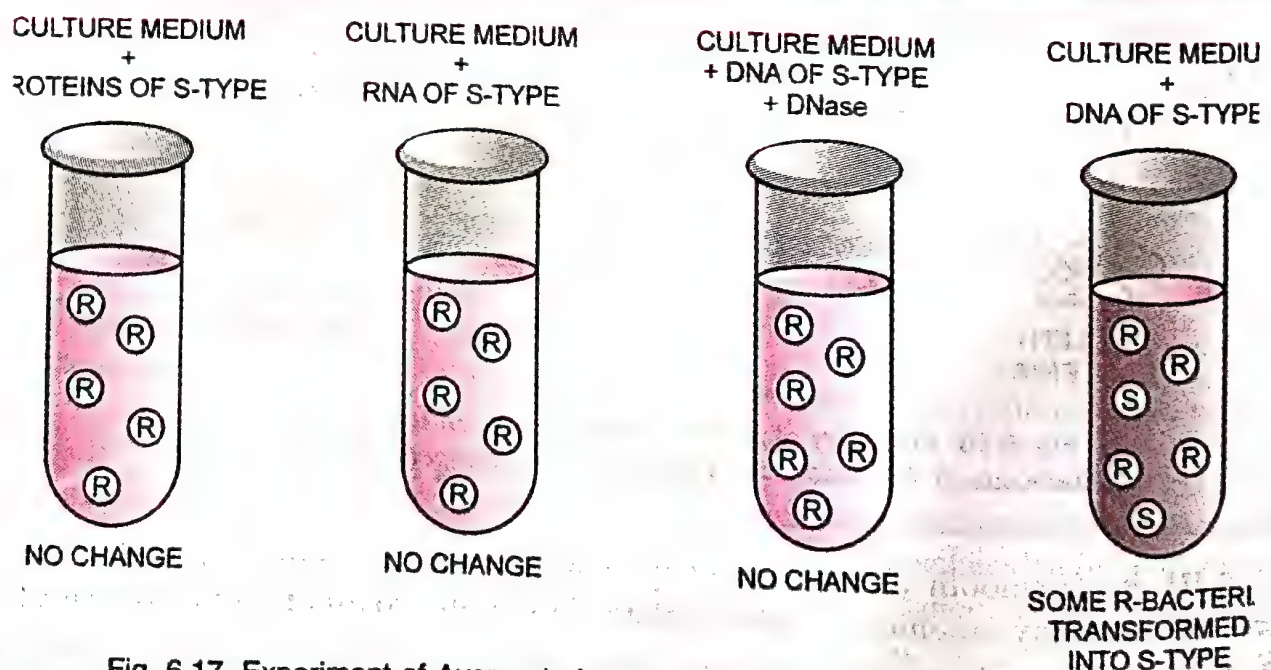


Fig. 6.17. Experiment of Avery *et al*, to prove that DNA is transforming principle.

Differences between DNA and DNase

DNA	DNase
<ol style="list-style-type: none"> 1. DNA is abbreviated form of deoxyribonucleic acid. 2. DNA is composed of deoxyribonucleotides. Each deoxyribonucleotide consists of phosphate, deoxyribose sugar and a nitrogenous base. 3. It is a genetic material in all living organisms and many viruses. 	<ol style="list-style-type: none"> 1. DNase is abbreviated form of deoxyribonuclease. 2. DNase is an enzyme. 3. It digests DNA oligonucleotides or nucleotides by cleaving the phosphodiester bonds.

The Genetic Material is DNA

The unequivocal (unmistakable) proof that DNA is the genetic material came from **transduction experiments** (Bacteriophage Experiments) of Alfred Hershey and Martha Chase (1952).

Hershey and Chase Experiment. Bacteriophages are bacterial viruses. T_2 is a bacteriophage which infects *Escherichia coli*, the bacterium present as commensal in human intestine. *Escherichia coli* can also be grown over culture medium. T_2 bacteriophage is made up of DNA and protein coat (capsid). Thus it is the most suitable material to determine whether DNA or protein contains genetic material.

Labelling of protein coat and DNA of bacteriophages with radioactive Traces. Hershey and chase (1952) grew two cultures of *Escherichia coli*. One culture was supplied with radio-active sulphur, ^{35}S . The other culture was provided with radioactive phosphorus, ^{32}P . Radioactive sulphur gets incorporated into sulphur containing amino acids (cysteine and methionine), and therefore, becomes part of bacterial proteins. Radioactive phosphorus gets incorporated into nucleotides which form nucleic acids, mostly DNA. Therefore, bacteria of both the cultures became labelled (Fig. 6.18).

After labelling, three steps were followed, i.e., infection, blending and centrifugation.

1. **Infection.** Both types of labelled phages (bacteriophages are commonly called phages) were allowed to infect normally cultured bacteria in separate experiments. DNA was introduced and protein coat was left out.

2. **Blending.** As the infection proceeded the bacterial cells were agitated in a blender to break the contact between virus and bacteria.

3. **Centrifugation.** The virus particles were separated from the bacteria by spinning them in a centrifuge.

The heavier (infected as well) bacteria settled down in the form of **pellet**. The **supernatant** contains lighter viral coats which do not enter the bacterial cells. Both the pellet and supernatant were analysed. It was found that phage with labelled protein did not make the bacteria labelled. Instead, radio-activity was restricted to the supernatant which was found to contain only empty phage capsids (protein coats; Fig. 6.19A).

In the second culture where bacteriophage labelled with radioactive DNA was introduced, it was found that shaking did not produce any radio-activity in the supernatant having empty capsids. Instead, the bacteria became labelled proving that only DNA of the phage entered the bacteria (Fig. 6.19B).

The progeny of the two types of bacteriophages was again tested for radio-activity. Radioactivity was absent in the viruses derived from parents having labelled protein. The viruses derived from parents having labelled DNA possessed radio-activity. *This shows that the genetic material is DNA and not the protein.*

Hershey and chase experiment is also called **blender experiment**.

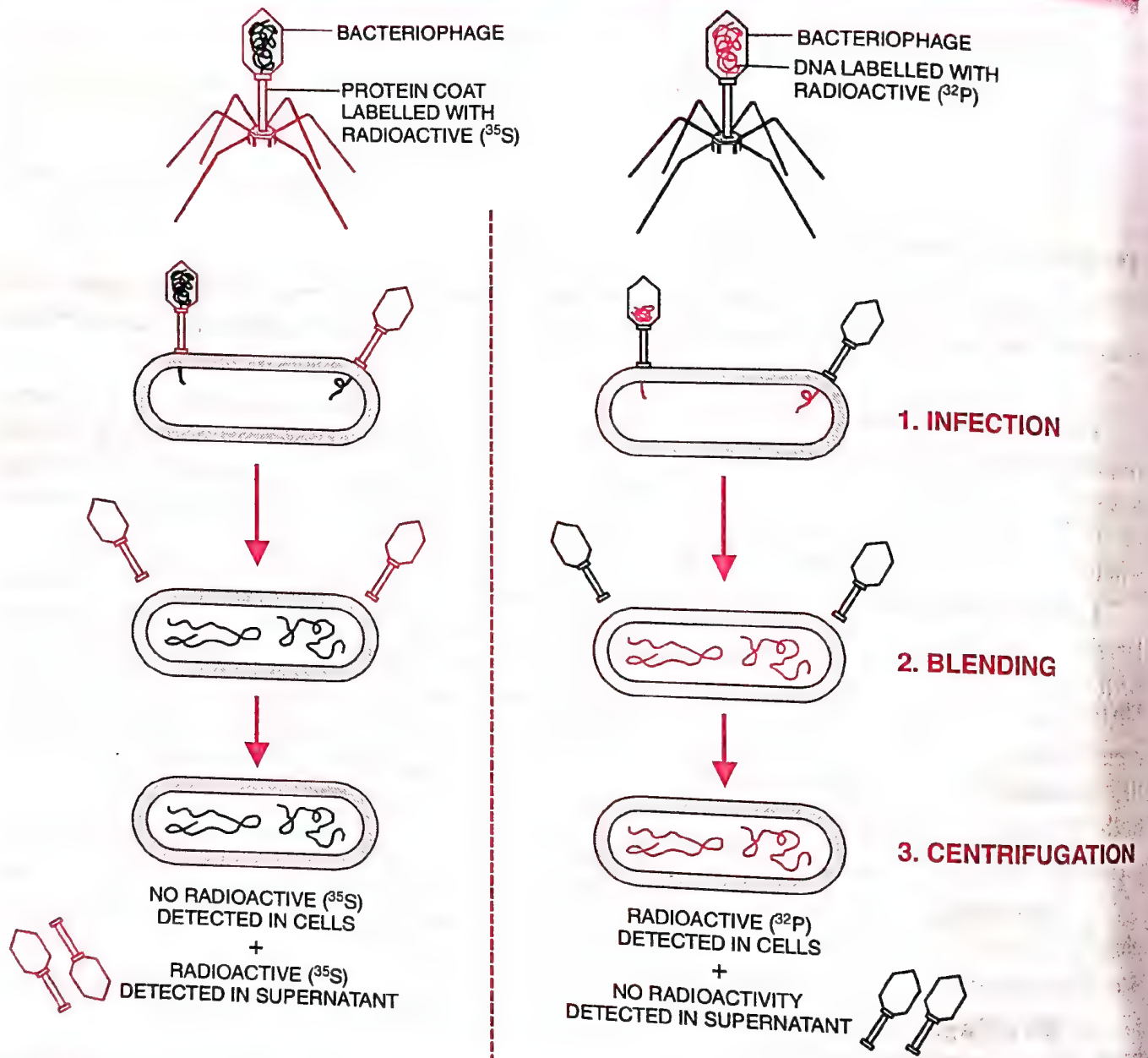


Fig. 6.18. The Hershey-Chase Experiment.

Properties of Genetic Material (DNA Versus RNA)

Now it is clear that the debate between proteins versus DNA as the genetic material was unequivocally resolved from Hershey-Chase experiment. However, it subsequently becomes clear that in some viruses RNA is the genetic material, e.g., Tobacco Mosaic Viruses, QB bacteriophage, etc.

Answer to some of the questions such as, why DNA is the predominant genetic material, whereas RNA performs dynamic functions of messenger and adapter has to be found from the differences between chemical structures of the two nucleic acid molecules.

Two Chemical differences Between DNA and RNA

DNA	RNA
1. The sugar molecule in DNA is deoxyribose sugar.	1. The sugar molecule in RNA is ribose.
2. The four nitrogenous bases found in DNA are	2. The four nitrogenous bases found in RNA are
(a) Adenine } (b) Guanine } Purines	(a) Adenine } (b) Guanine } Purines
(c) Cytosine } (d) Thymine } Pyrimidines	(c) Cytosine } (d) Uracil } Pyrimidines

Requirement of Genetic Material. A molecule that can act as a genetic material must fulfill the following criteria.

1. **Replication.** It should be able to generate its replica.

2. **Stability.** It should chemically and structurally be stable.

3. **Mutation.** It should provide the scope for slow changes (mutation) that are required for evolution.

4. **Expression.** It should be able to express itself in the form of 'Mendelian Characters'.

DNA is Highly Stable. The genetic material should be stable enough not to change with different stages of life cycle, age or with change in physiology of the organism. Stability as one of the properties of genetic material was very evident in Griffith's 'transforming principle' itself that heat, which killed the bacteria, at least did not destroy some of the properties of genetic material.

(a) The two strands of DNA being complementary if separated by heating come together, when appropriate conditions are provided.

(b) 2' -OH group present at every nucleotide in RNA is a reactive group and makes RNA labile and easily degradable.

(c) RNA is also now known to be catalytic, hence reactive.

(d) Presence of thymine (5-Methyl uracil) at the place of uracil also confers additional stability to DNA.

(e) RNA being unstable, mutates at a faster rate. Consequently, viruses having RNA genome can directly code for the synthesis of proteins, hence can easily express the characters.

Therefore, DNA chemically is less reactive and structurally more stable when compared to RNA. Therefore, among the two nucleic acids, the DNA is a better genetic material.

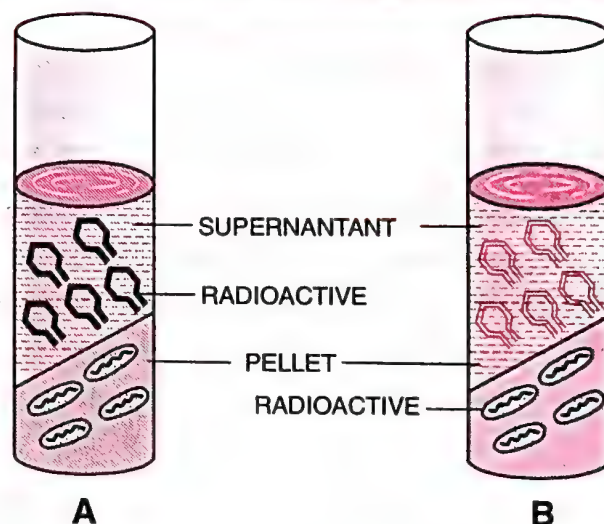


Fig. 6.19. A, First Culture. B, Second Culture.

RNA World

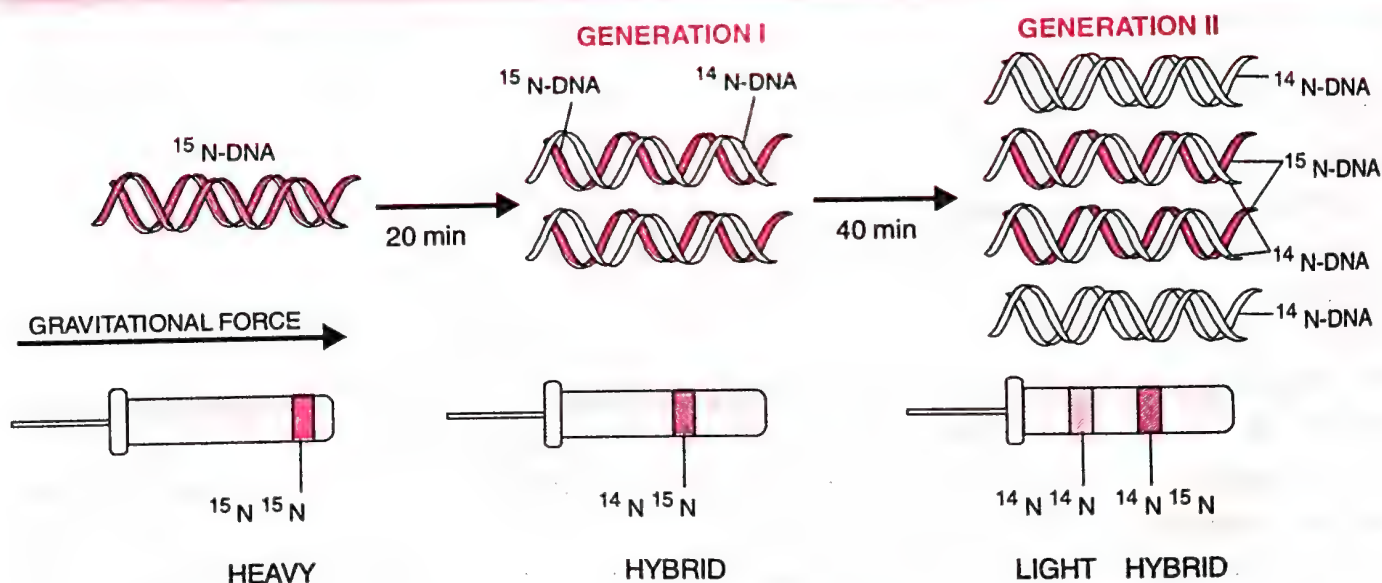
There is little doubt that early life was RNA centric with every important function being controlled by it. The first genetic material was RNA. Metabolism, splicing and translation evolved around RNA. The first biocatalysts were RNAs. Even now some enzymes are made of RNAs, e.g., ribozyme. RNAs worked well in early unstable environmental conditions. As the environment became stable, RNAs were replaced in two of its functions (i) By small chemical modifications RNA gave rise to DNA as genetic material. DNA being double stranded with complementary strands is not only more stable but also resists changes as it has evolved a process of repair. (ii) For biocatalysis, RNA was replaced by protein enzymes. The latter were more stable, more efficient and more varied. This increased metabolic activity and paved the way for evolution of more complex organisms.

REPLICATION

Replication is a duplication process requiring copying from a template. It occurs in case of DNA. **Watson and Crick** had immediately proposed a scheme for DNA replication while proposing the double helical structure of DNA (1953). The scheme suggested that the two strands would separate and act as template for the synthesis of new complementary strands. After the completion of replication, each DNA molecule would have one parental and one newly synthesised strand. This scheme was termed as **semiconservative DNA replication**.

The Experimental Proof

Experiment 1. DNA Replication is Semiconservative. **Matthew Meselson and Franklin Stahl (1958)** performed following experiment using heavy nitrogen (^{15}N) in *E. coli*.



(Separation of DNA by Centrifugation)

Fig. 6.20. Meselson and Stahl's Experiment to prove semiconservative replication of DNA.

(i) They grew *E. coli* in a medium containing $^{15}\text{NH}_4\text{Cl}$ as the only nitrogen source for many generations. ^{15}N is the heavy isotope of nitrogen. ^{15}N was incorporated into newly synthesised DNA as well as other nitrogen-containing compounds. This heavy DNA molecule

^{15}N is not a radioactive isotope. It is a heavy isotope of N and can be separated from ^{14}N by density gradient centrifugation.

could be distinguished from the normal DNA by centrifugation in a cesium chloride (CsCl) density gradient. A dense solution of CsCl, on centrifugation, forms density gradient bands of a solution of lower density at the top that increases gradually towards bottom with highest density.

(ii) Then they transferred the cells into a medium with normal $^{14}\text{NH}_4\text{Cl}$ and took samples at various definite time intervals as the cells multiplied and extracted the DNA that remained as double-stranded helix. The various samples were separated independently on CsCl gradients to measure the densities of DNA.

(iii) Thus, the DNA that was extracted from the culture after 1st generation, *i.e.*, just after 20 minutes had a hybrid or intermediate density. DNA extracted from the culture after another generation, *i.e.*, 2nd generation or 40 minutes was composed of equal amounts of this hybrid DNA ($\text{N}^{14}\text{N}^{15}$) and of light DNA ($\text{N}^{14}\text{N}^{14}$). Increase in the amount of light DNA and decrease in hybrid DNA amount can be possible due to semiconservative mode of replication.

Experiment 2 Chromosome Replication is Semiconservative. Taylor *et al* (1957) have proved semiconservative mode of chromosome replication in eukaryotes using radioactive tritiated thymidine (^3H -thymidine) in roots of *Vicia faba* (faba beans).

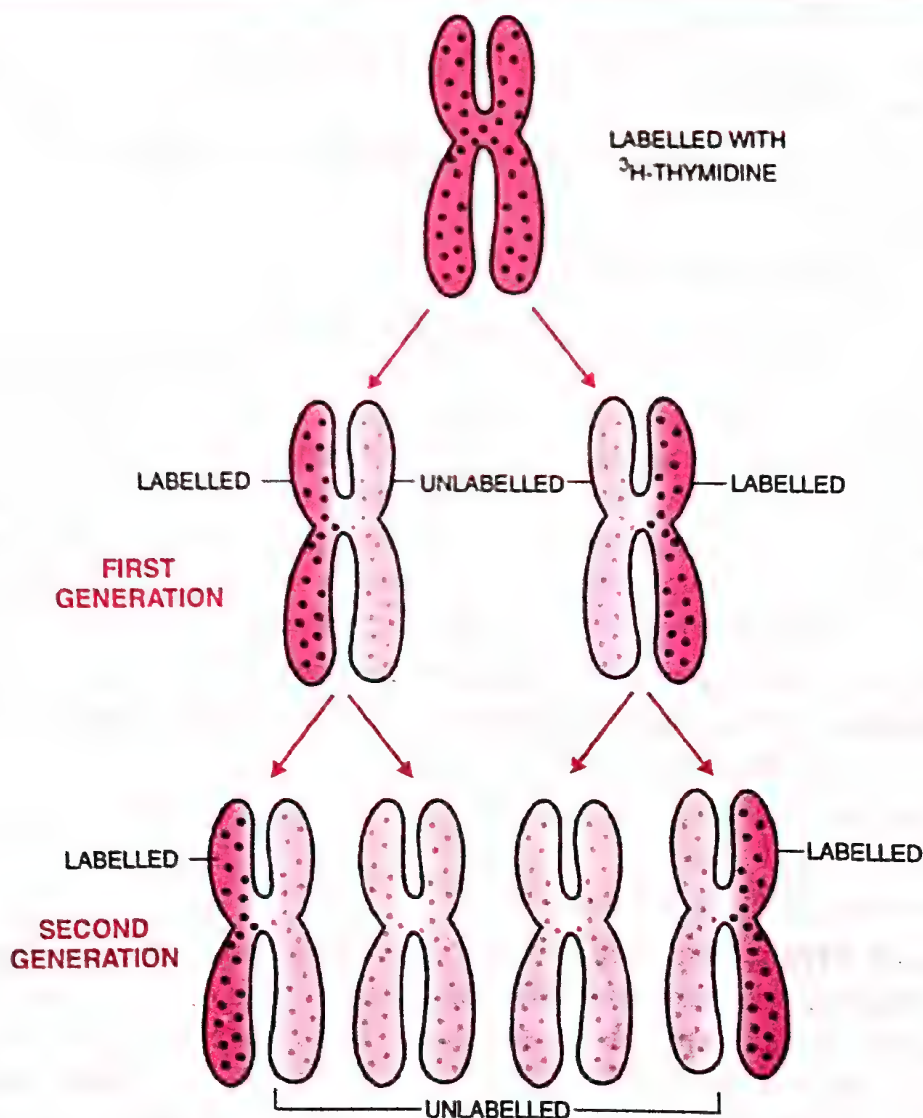


Fig. 6.21. Experiment of Taylor *et al* (1958) to show semi-conservative replication of chromosomes.

They supplied roots of *Vicia faba* with radioactive tritiated thymidine for a few days till all the chromosomes of dividing cells became radioactive. Therefore, the radioactive chemical was withdrawn and replaced with non-radioactive chemical. It was found that in first generation, one of the two chromatids of each chromosome remained radioactive while the second chromatid was non-radioactive. In the second cell generation 50% of the chromosomes were unlabelled while in the remaining 50%, labelling remained only in one of the two strands (Fig. 6.20). This is possible only if out of the two strands of a chromosome, one is formed afresh while the other is conserved at each replication. This is semiconservative replication.

The Enzymes

A large number of enzymes are required for DNA replication. DNA-dependent DNA polymerase is the main enzyme which takes part in combining deoxyribose nucleotides to form new DNA strands. DNA polymerase was discovered by Kornberg (1957). Prokaryotes (e.g., *E. coli*) have 3 main types of DNA polymerases, i.e., DNA polymerase I, II and III. Polymerase III is main enzyme responsible for DNA replication in *E. coli*. Polymerase I (also called Kornberg enzyme) and II function primarily in DNA repair. Eukaryotes have 5 types of DNA polymerases — α , β , γ , δ and ϵ . Polymerase α is required for initiation of replication, β for DNA repair, γ for mitochondrial DNA repair, δ for replication activity and ϵ in polymerase activity of He La cells.

DNA ligase. DNA ligase enzyme joins newly synthesized fragments of DNA. DNA ligase was discovered by Khorana (1967).

The other enzymes required for DNA replication are primase (an RNA polymerase), topoisomerase, helicase, etc.

Mechanism of DNA Replication

The main enzyme involved in replication is DNA-dependent DNA polymerase. It is named so because it uses a DNA template to catalyse the polymerisation of deoxynucleotides. These enzymes are highly efficient enzymes as they have to catalyse polymerisation of a large number of nucleotides in a very short time. *E. coli* that has only 4.6×10^6 bp (as compared with human whose diploid content is 6.6×10^9 bp), completes the process of replication within 38 minutes; that means the average rate of polymerisation has to be approximately 2000 bp per second. Any mistake during replication would result into mutations. Furthermore, energetically replication is a very expensive process.

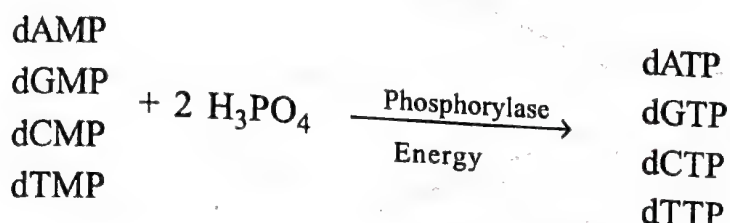
Replication in eukaryotes occurs in the nucleus during the S-phase of the cell cycle. It is semidiscontinuous in eukaryotes. In prokaryotes, replication takes place in the cytoplasm. DNA replication in bacteria occurs prior to fission.

DNA replication is a complex multistep process that requires a number of enzymes, protein factors and metal ions.

Replication takes place as follows :—

1. **Origin of Replication.** Replication begins at a particular spot called **origin of replication** or **ori**. Bacterial and viral DNA has a single origin of replication. It functions as a single replicating unit or **replicon**. In eucaryotic DNA there are a number of origins of replication. It has several replicating segments or **replicons**, i.e., **multirepliconic**. In the absence of ori, replication will not occur. The requirement of a vector for recombinant DNA technology is to obtain origin of replication.

2. Activation of Deoxyribonucleotides. Deoxyribonucleotides occur freely inside the nucleoplasm. They are of four types— dAMP (deoxyadenosine monophosphate), dGMP (deoxyguanosine monophosphate), dCMP (deoxycytidine monophosphate) and dTMP (deoxythymidine monophosphate). They are first phosphorylated and changed to active forms which have three phosphate residues instead of one. Enzymes **phosphorylase** is required along with energy. The phosphorylated nucleotides are dATP (deoxyadenosine triphosphate), dGTP (deoxyguanosine triphosphate), dCTP (deoxycytidine triphosphate) and dTTP (deoxythymidine triphosphate).



Deoxyribonucleoside triphosphates serve dual purposes. In addition to acting as substrates, they provide energy for polymerisation reaction, because the two terminal phosphates in a deoxynucleoside triphosphates are high energy phosphates, same as in case of ATP.

3. Exposure of Parent DNA Strands. Enzyme **helicase** (unwindase) acts over the *ori* site and unwinds the two strands of DNA by destroying hydrogen bonds. Unwinding of DNA molecule into two strands results in the formation of Y-shaped structure, called **replication fork** (Y fork). These exposed single strands are stabilised with the help of single strand binding proteins (SSBP). Due to unwinding, a supercoiling gets developed on the end of DNA opposite to replicating fork. This tension is released by enzyme **topoisomerase**. In prokaryotes, **DNA gyrase** has topoisomerase activity.

4. Formation of RNA Primer. At the free 3' end of one strand and fork end of the second strand a small strand of RNA is synthesized with the help of DNA-dependent enzyme **RNA polymerase** or **primase**. The synthesized RNA is called **RNA primer**. It is 4–12 nucleotides long. RNA primer functions as 5' end of the new strand (to be synthesized). It provides 3–OH group for joining of DNA nucleotides.

5. Base Pairing. The two separated DNA strands in the area of replication fork now function as their nitrogenous bases attract complementary phosphorylated nucleotides — dATP opposite T, dTTP opposite A, dCTP oppo-

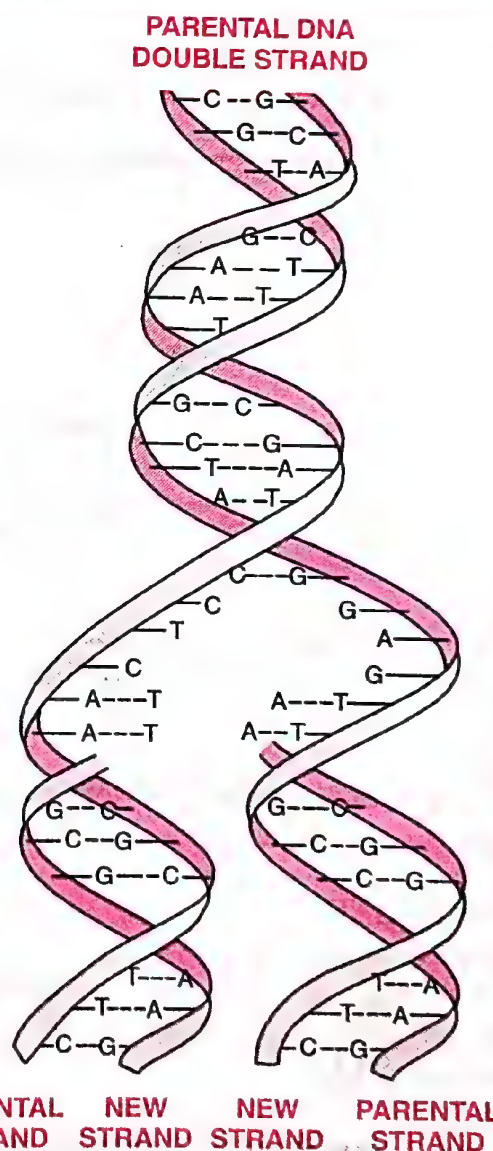


Fig. 6.22. Semi-conservative replication of DNA.

site G, dGTP opposite C. Enzyme **pyrophosphatase** removes two phosphates from phosphorylated nucleotides and change them into monophosphate state. It releases energy which is used in building hydrogen bonds.

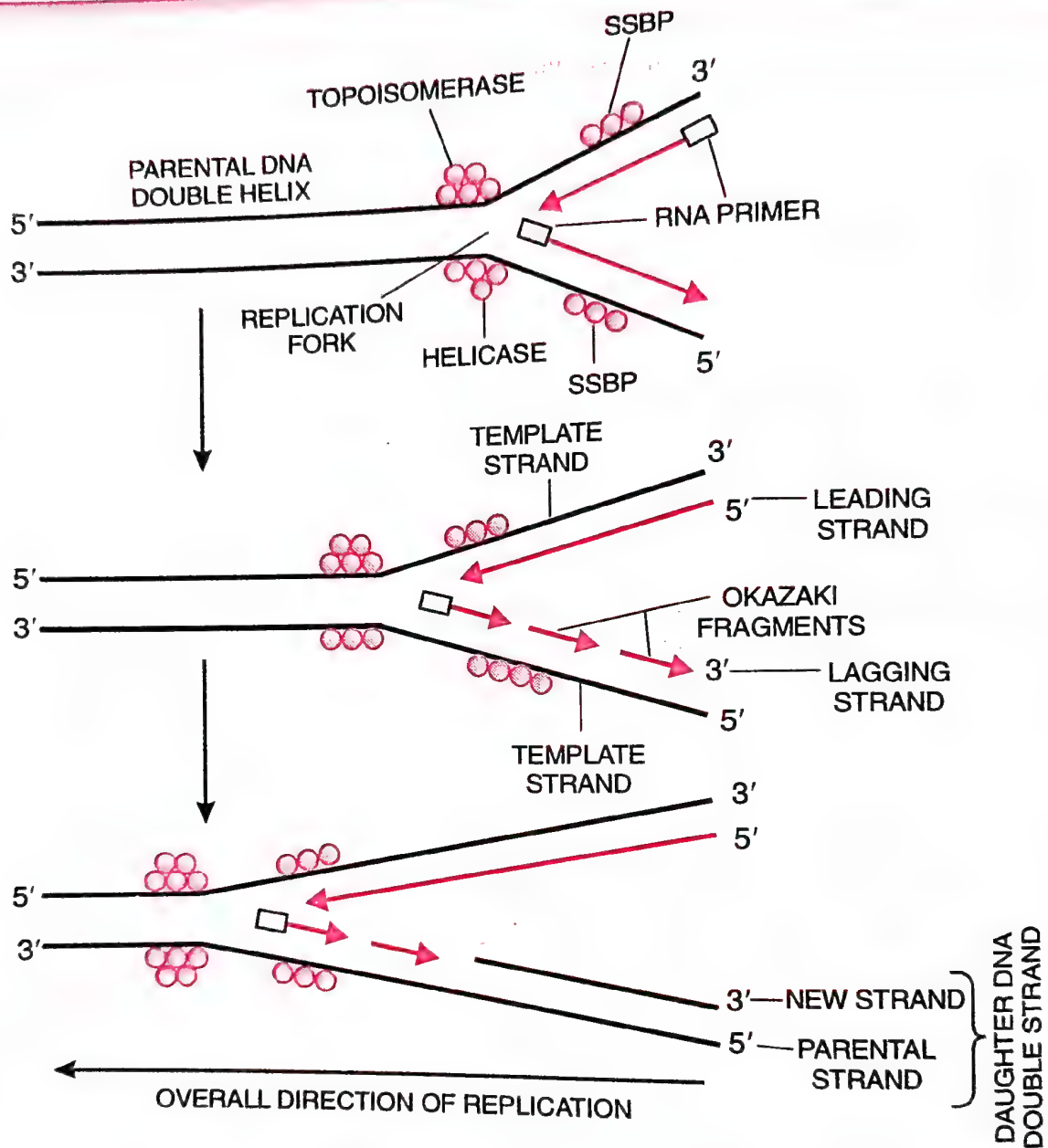


Fig. 6.23. Replication of DNA, continuous over one strand and discontinuous over the other strand.

dATP
dGTP
dCTP
dTTP

Pyrophosphatase →

dAMP + 2 Pi + Energy
dGMP + 2 Pi + Energy
dCMP + 2 Pi + Energy
dTMP + 2 Pi + Energy

6. New Strand Formation. It requires DNA polymerase III (Kornberg, 1956) in prokaryotes and polymerase δ/ϵ in eukaryotes. DNA polymerase III is a complex enzyme having seven subunits ($\alpha, \beta, \delta, \gamma, \epsilon, \theta, \tau$). In the presence of Mg^{2+} , ATP (GTP), TPP and DNA

polymerase III, the adjacent nucleotides found attached to nitrogen bases of each template DNA strand establish phosphodiester bonds and get linked to form replicated DNA strand. As replication proceeds, new areas of parent DNA duplex unwind and separate so that replication proceeds rapidly from the place of origin towards the other end. RNA primer is removed and the gap filled with complementary nucleotides by means of DNA polymerase I. Since the two strands of DNA run in antiparallel directions, the two templates provide different ends for replication. Replication over the two templates thus proceeds in opposite directions. One strand with polarity $3' \rightarrow 5'$ forms its complementary strand continuously because 3' end of the latter is always open for elongation. It is called **leading strand**. Replication is discontinuous on the other template with polarity $5' \rightarrow 3'$ because only a short segment of DNA strand can be built in $5' \rightarrow 3'$ direction due to exposure of a small stretch of template at one time. Short segments of replicated DNA are called **Okazaki fragments** (= Okasaki segments ; Reiji Okazaki, 1968). Each of them has 1000- 2000 bp in prokaryotes and 100–200 bp in eukaryotes. An RNA primer is also required every time a new Okazaki fragment is to be built. After replacing RNA primer with deoxyribonucleotides and their polymerisation, Okazaki fragments are joined together by means of enzyme, DNA ligase (Khorana, 1967). DNA strand built up of Okazaki fragments is called **lagging strand**.

As one strand grows continuously while the other strand is formed discontinuously, DNA replication is **semidiscontinuous**.

Differences Between Leading Strand and Lagging Strand

Leading Strand	Lagging Strand
<ol style="list-style-type: none"> 1. It is a replicated strand of DNA which grows continuously without any gap. 2. It does not require DNA ligase for its growth. 3. The direction of growth of the leading strand is $5' \rightarrow 3'$. 4. Only a single RNA primer is required. 5. Formation of leading strand is quite rapid. 6. Its template opens in $3' \rightarrow 5'$ direction. 7. Formation of leading strand begins immediately at the beginning of replication. 	<ol style="list-style-type: none"> 1. Lagging strand is a replicated strand of DNA which is formed in short segments called Okazaki fragments. Its growth is discontinuous. 2. DNA-ligase is required for joining Okazaki fragments. 3. The direction of growth of the lagging strand is $3' \rightarrow 5'$ though in each Okazaki fragment it is $5' \rightarrow 3'$. 4. Starting of each Okazaki fragment requires a new RNA. 5. Formation of lagging strand is slower. 6. Its template opens in $5' \rightarrow 3'$ direction. 7. Formation of lagging strand begins a bit later than that of leading strand.

7. Proof-reading. A wrong base is sometimes introduced during replication. The frequency is one in ten thousand. DNA polymerase III is able to sense the same. It goes back, removes the wrong base, allows addition of proper base and then proceeds forward. However, even DNA polymerase III is unable to distinguish uracil from thymine so that it is often incorporated in place of thymine. Such a mismatching is corrected by means of a number of enzymes.

DNA polymerase I (Kornberg, 1969) removes the mismatched or wrong nucleotides if present and synthesises a correct replacement by using the intact strand as template. The newly formed segment is sealed by DNA ligase.

Differences between Prokaryotic DNA Replication and Eukaryotic DNA Replication	
Prokaryotic DNA Replication	Eukaryotic DNA Replication
<ol style="list-style-type: none"> 1. It occurs inside the cytoplasm. 2. There is single origin of replication. 3. DNA polymerase III carries out both initiation and elongation. 4. DNA repair and gap filling are done by DNA polymerase I. 5. RNA primer is removed by DNA polymerase I. 6. Okazaki fragments are large, 1000-2000 nucleotides long. 7. Replication is very rapid, some 2000 bp per second. 8. DNA gyrase is needed. 	<ol style="list-style-type: none"> 1. It occurs inside the nucleus. 2. Origin of replications are numerous. 3. Initiation is carried out by DNA polymerase α while elongation by DNA polymerase δ and ϵ. 4. The same are performed by DNA polymerase β. 5. RNA primer is removed by DNA polymerase β. 6. Okazaki fragments are short, 100-200 nucleotides long. 7. Replication is slow, some 100 nucleotides per second. 8. DNA gyrase is not needed.

What is Gene ?

The term gene was introduced by Johanssen in 1909. Prior to him Mendel had used the word factor for a specific, distinct, particulate unit of inheritance that takes part in expression of a trait. Johanssen has defined gene as *an elementary unit of inheritance which can be assigned to a particular trait*. Morgan's work suggested gene to be the shortest segment of chromosome which can be separated through crossing over, can undergo mutation and influence expression of one or more traits. Presently, *a gene is defined as a unit of inheritance composed of a segment of DNA or chromosome situated at a specific locus (gene locus) which carries coded information associated with a specific function and can undergo crossing over as well as mutation*.

Characteristics of Gene

1. **Replication.** Gene is a unit of genetic material which is able to replicate.
2. **Recombination.** It is a unit of recombination, i.e., capable of undergoing crossing over.
3. **Mutation.** It is a unit of genetic material which undergoes mutation.
4. **Somatic Structure/Function.** Gene is a unit of heredity connected with somatic structure or function that leads to a phenotypic expression. Thus gene regulates structure or metabolism.
5. **Development and Differentiation.** Gene governs development and differentiation.

Genes and Enzymes

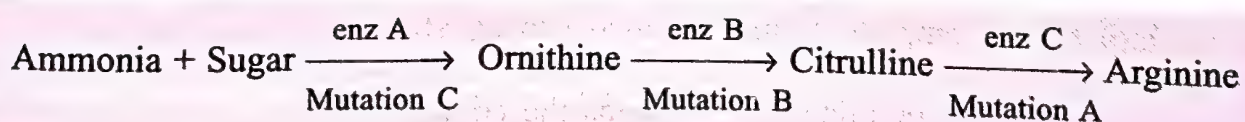
Archibald Garrod (Father of Biochemical Genetics) was the first to hint that genes operate through enzymes. He studied a number of inherited human disorders and found that they are **inborn errors of metabolism** or failure of metabolic machinery of the organism to perform a particular function due to formation of defective enzymes associated with inheritance of defective genes. Garrod (1902) studied **alkaptonuria** which is a genetic disorder or disease of human beings characterised by brown or black colour of the exposed urine. He came to the conclusion through pedigree analysis that the disease was caused by

the inheritance of a pair of recessive genes. **Alkapton** or **homogentisic acid** is produced in human beings. The acid is formed during metabolism of two amino acids, phenylalanine and tyrosine. Normally, alkapton or homogentisic acid is oxidised to CO_2 and H_2O with the help of alkapton oxidase.



However, in the patient suffering from alkaptonuria, the enzyme is defective and unable to metabolise the acid. As a result alkapton or homogentisic acid accumulates. It shows that genes work through enzymes.

One-Gene One-Enzyme Hypothesis. It is hypothesis put forward by Beadle and Tatum (1948) which states that a gene controls a structural or functional trait through controlling the synthesis of a specific protein or enzyme formed by the latter. They arrived at this conclusion through the following observations. (a) Beadle and coworkers found that the red eye colour of *Drosophila melanogaster* is controlled by two genes and is caused by the blending of brown and vermillion pigments. A piece of larva destined to form vermillion eye can be made to produce red eye colour if it is placed in the body cavity of larva having red eye because the latter provides its enzyme for brown colour which the transplant lacks. (b) In 1944, Beadle and Tatum irradiated *Neurospora crassa* with X-rays and obtained a number of nutritional mutants called **auxotrophs**. An auxotroph or nutritional mutant is that mutant which is not able to prepare its own metabolites from the raw materials obtained from outside. Therefore, it cannot live in natural environment but can be maintained in culture by providing the required metabolites. The wild type is called **prototroph**. A prototroph or wild type is the normal individual which can synthesise all the complex metabolites required for its growth from raw materials obtained from outside. It can grow in the laboratory on **minimal medium** consisting of ammonia, sugar, salts and biotin. Beadle and Tatum found three types of auxotrophs requiring amino acids ornithine, citrulline and arginine. The prototrophs were found to have amino acid arginine in their body. Obviously it has been synthesised from ammonia and sugar of the minimal medium. Auxotroph requiring ornithine for its growth does not contain arginine and dies due to protein deficiency. When supplied with ornithine, it is found to possess arginine. Auxotroph requiring citrulline possesses ornithine but no arginine. When citrulline is supplied, the auxotroph comes to have arginine. The nutritional mutant requiring arginine contains both ornithine and citrulline. It seems that arginine is synthesised from ammonia and sugar of the minimal medium through at least three steps each requiring its own enzyme.



Beadle and Tatum reasoned that defective enzymes are due to defective or mutant genes. Hence, genes express their effect by controlling the synthesis of enzymes. In 1948, Beadle and Tatum proposed that a gene controls the synthesis of one enzyme. They were awarded Nobel Prize for this work in 1958. However, a number of draw backs are present in the theory.

Defects in One Gene One Enzyme Hypothesis. One gene one enzyme hypothesis has some defects: (i) All genes do not produce enzymes or their components. Some of them

control other genes. (ii) Enzymes are generally proteinaceous in nature but all proteins are not enzymes. (iii) Some RNAs also exhibit enzyme activity. (iv) A protein or enzyme molecule may consist of one or more types of polypeptides.

One-Gene One-Polypeptide Hypothesis. Yanofsky *et al* (1965) found that the enzyme tryptophan synthetase of bacterium *Escherichia coli* consists of two separate polypeptides, A and B. Polypeptide A is of α -type while polypeptide B is of β -type. The synthesis of the two polypeptides is controlled by different genes, *trp A* and *trp B*. A change in any of the two genes causes inactivation of tryptophan synthetase through nonsynthesis of α or β -polypeptide. Inactivation of enzyme stops the synthesis of tryptophan from indole 3-glycerol phosphate and serine. A similar situation is found in case of the formation of haemoglobin molecule. Haemoglobin consists of four polypeptides, 2α and 2β . The synthesis of the two types of polypeptides is controlled by two different genes situated on different chromosomes. Therefore, one gene one enzyme hypothesis was changed to one gene one polypeptide hypothesis (Ingram, 1953). The hypothesis states that a structural gene specifies the synthesis of a single polypeptide.

Gene Versus Cistron

The early work on mutations suggested that gene is the shortest part of chromosome which can undergo mutation. However, mutation can occur even in a single nucleotide. Beadle and Tatum defined gene to be a *unit of hereditary material that specifies a single enzyme*. Meanwhile it was found that hereditary material of chromosome is DNA. Therefore, gene was considered to be a segment of DNA. Yanofsky *et al* (1965) found that a gene specifies only a single polypeptide. However, DNA not only specifies the synthesis of polypeptides through mRNAs but also synthesises other RNAs. Therefore, the term gene is now-a-days being replaced by **cistron**. *Cistron is a segment of DNA consisting of a stretch of base sequences that codes for one polypeptide chain, one transfer RNA (tRNA), ribosomal RNA (rRNA) molecule or performs any other specific function in connection with transcription, including controlling the functioning of other cistrons (operon model of gene action).*

TRANSCRIPTION

The process of copying genetic information from template strand of DNA into RNA is called **transcription**. It is mediated by **RNA polymerase**. Transcription takes place in the nucleus of eukaryotic cells.

The strand of DNA with polarity $3' \rightarrow 5'$ that directs synthesis of RNA, is called **template strand** or **antisense strand**. The other strand of DNA with polarity $5' \rightarrow 3'$ is complementary to the template strand is called **coding strand** or **sense strand** because genetic code present in this strand is similar to genetic code (based on mRNA) except that uracil (U) is replaced by thymine (T). It means the coding strand of DNA has the same sequence of nitrogenous bases as the RNA transcript except that in RNA T (thymine) is substituted by U (uracil). It has the same polarity as the RNA transcript.

Transcription Unit (Fig. 6.24)

Transcription unit in DNA molecule comprises three regions (i) A Promoter, (ii) The structural gene and (iii) A terminator.

Now a transcription unit is defined as the segment of DNA between the sites of initiation and termination of transcription by RNA polymerase, more than one gene may reside in a transcription unit.

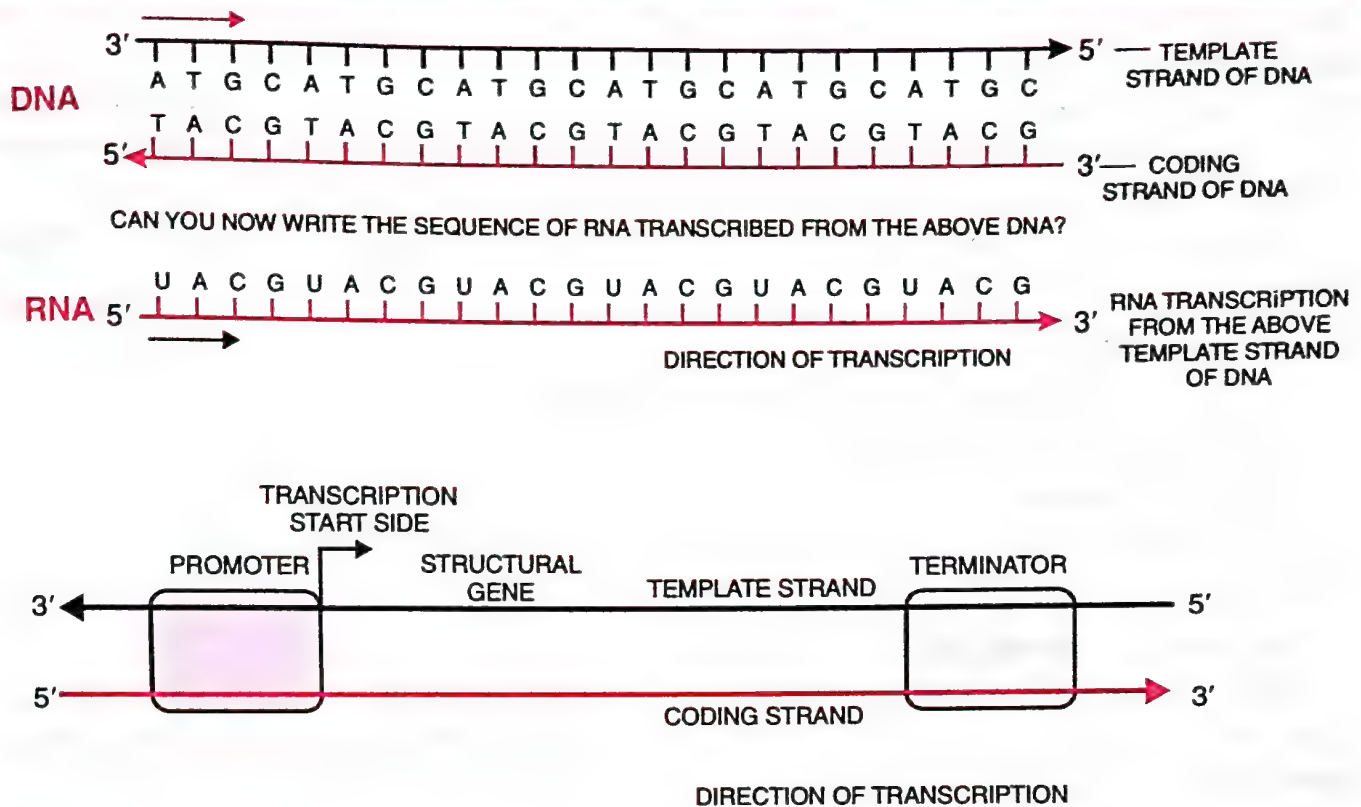


Fig. 6.24. Schematic structure of a transcription unit.

Promoter. It is a region on DNA molecule to which an **RNA polymerase** binds and initiates transcription. Promoter is located upstream (to the left) of the structural gene, *i.e.*, towards 5' end of coding strand, 3' end of template strand. Promoter has different parts for attachment to various transcription factors. In most eukaryotes, the promoter has an AT rich region called **TATA box** (Goldberg–Hogness box). The area has a groove to which specific protein components can combine. TATA box is also called **Pribnow box** (after its discoverer Pribnow, 1975) in prokaryotes and **Hogness box** (after its discoverer Hogness) in eukaryotes. Besides a promoter, eukaryotes also require an **enhancer**.

Terminator. This region on DNA molecule is present downstream (to the right) of the structural gene, *i.e.*, towards 3' end of coding strand, 5' end of template strand. Terminator usually defines the end of the process of transcription.

Structural Gene. It is the area of template strand that is involved in transcription or formation of RNA. Structural gene is of two types — **monocistronic** and **polycistronic**. The monocistronic structural gene carries information for synthesis of one polypeptide chain. They are mostly found in eukaryotes. The polycistronic structural gene carries information for synthesis of more than one polypeptide chains. They are mostly found in prokaryotes.

Transcription Unit and the Gene

A gene is defined as the functional unit of inheritance. Gene are located on the DNA and it is difficult to literally define a gene in terms of DNA sequence. The DNA sequence coding for tRNA or rRNA molecule also defines a gene. Cistron is defined as a functional unit of gene, it is a segment of DNA coding for a polypeptide.

The structural gene in a transcription unit is monocistronic (mostly in eukaryotes) and polycistronic (mostly in prokaryotes or bacteria). Monocistronic gene synthesises one type

of polypeptide or protein. Polycistronic gene synthesises different proteins or polypeptides. The monocistronic structural genes have interrupted coding sequences, *i.e.*, the genes in eukaryotes are split. The coding sequences or expressed sequences are defined as **exons** which appear in mature or processed RNA. The exons are interrupted by **introns**. Introns are intervening sequences that do not appear in mature or processed RNA. The split-gene arrangement further complicates the definition of a gene in terms of a DNA segment.

The mechanism of RNA synthesis was worked out in the late 1950s by Horwitz, Weiss and Stevens, by *in vitro* experiments.

Materials Required for Transcription

RNA transcription requires the following materials.

- (i) The enzyme RNA polymerase
- (ii) A DNA template
- (iii) Four types of ribonucleotides triphosphates (ATP, CTP, GTP and UTP)
- (iv) Divalent metal ions Mg^{2+} or Mn^{2+} as a cofactor.

No primer is needed for RNA synthesis.

There is single **RNA polymerase** in prokaryotes which synthesizes all types of RNAs. Eukaryotes have three types of RNA polymerases (i) **RNA Polymerase I** (ii) **RNA Polymerase II** and (iii) **RNA Polymerase III**.

Prokaryotic RNA polymerase has important **sigma (δ) factor** (also called **initiation factor**). Sigma factor is a protein needed only for initiation of RNA synthesis (transcription). It enables specific binding of RNA polymerase to gene promoter. The part of the polymerase enzyme minus sigma factor is called **core enzyme**.

Termination of transcription requires **rho (ρ) factor** (also called **termination factor**). Rho factor is a prokaryotic protein which is involved in the termination of transcription.

Differences between DNA Polymerase and RNA Polymerase

<i>DNA Polymerase</i>	<i>RNA Polymerase</i>
<ol style="list-style-type: none"> 1. It takes part in replication. 2. It requires a primer for its activity. 3. It is useful for both the strands of DNA. 4. It uses deoxyribonucleotides. 5. It can perform proof reading. 	<ol style="list-style-type: none"> 1. It takes part in transcription. 2. It does not require a primer. 3. It acts on only the template strand of DNA. 4. It uses ribonucleotides. 5. Proof reading is absent.

Process of Transcription

The process of transcription is described separately in prokaryotes and eukaryotes.

(A) Transcription in Prokaryotes

It occurs in *cytoplasm* with the help of **DNA-dependent RNA polymerase** that catalyses transcription of all the three types of RNAs (*e.g.*, mRNA, tRNA and rRNA) in bacteria. All three RNAs are needed to synthesize a protein in a cell. In prokaryotes the structural genes are polycistronic and continuous. The process of transcription completes in 3-5 steps.

(i) **Initiation**. RNA polymerase reaches the promoter region and binds to it. RNA polymerase has a **sigma (σ) factor** (also called initiation factor). The enzyme recognizes the promoter by its sigma factor. RNA polymerase initiates transcription. It uses nucleoside

triphosphates as substrate and polymerases in a template depended fashion following the rule of complementarity. It also facilitates opening of helix.

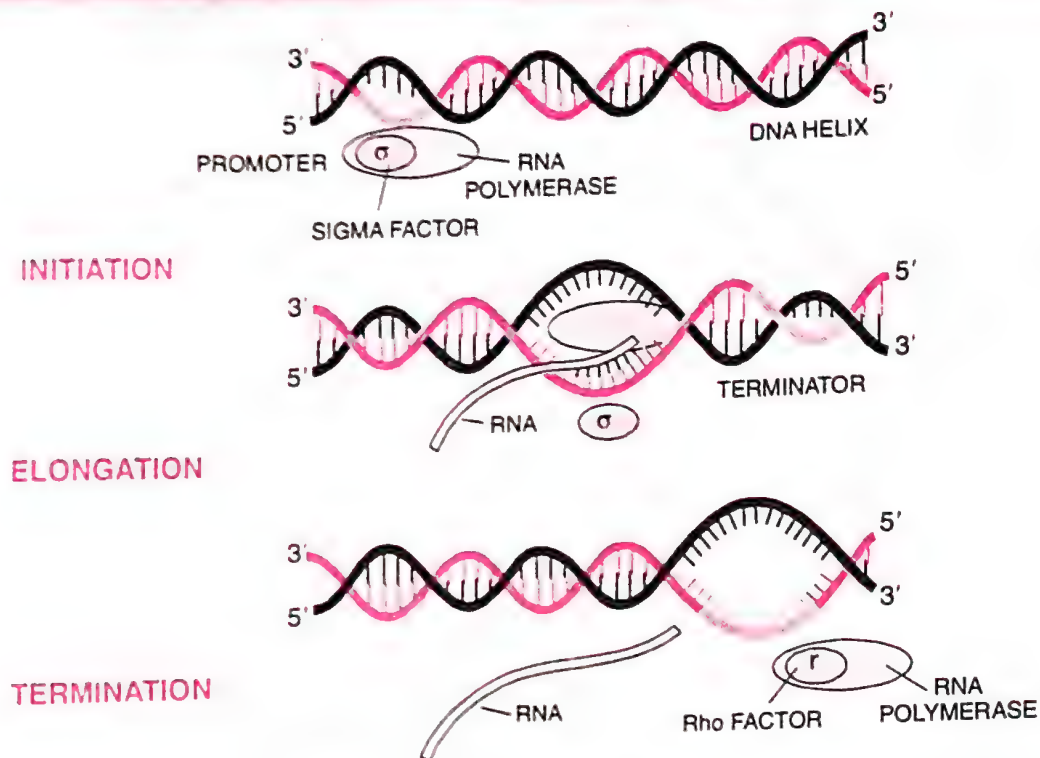


Fig. 6.25. Process of Transcription in Bacteria.

(ii) **Elongation.** The RNA polymerase (**core enzyme**) in the presence of energy and Mg^{2+} can catalyse the process of elongation. As the enzyme moves along the DNA template, RNA chain becomes longer. Synthesis of RNA continues till the enzyme reaches the terminator.

(iii) **Termination.** When the RNA polymerase reaches the terminator region a specific chain terminating protein called **rho (ρ) factor** (also called termination factor) stops the synthesis of RNA chain. It separates RNA polymerase as well as the newly formed RNA strand. The RNA and RNA polymerase fall off and it results in the termination of transcription.

In bacteria (a) *mRNA* does not require any processing to become active. (b) Transcription and translation take place in the same compartment as there is no separation of cytosol and nucleus. (c) Many times the translation can begin much before the *mRNA* is fully transcribed. Thus, the transcription and translation can be coupled.

(B) Transcription in Eukaryotes

Transcription in eukaryotes is more complex than that of prokaryotic transcription. It is described below.

Eukaryotic transcription occurs inside nucleus and two types of semi-autonomous cell organelles (e.g., mitochondria and plastids). It occurs in G_1 and G_2 phases of cell cycle. Eukaryotes have three types of RNA polymerases. Their functions are given below.

- RNA Polymerase I** transcribes *rRNAs* (28S, 18S and 5.8S).
- RNA polymerase II** transcribes precursor of *mRNA*, the **heterogenous nuclear RNA (hnRNA)**.
- RNA polymerase III** is responsible for transcription of *tRNA*, **5SrRNA** and **snRNAs** (small nuclear RNAs).

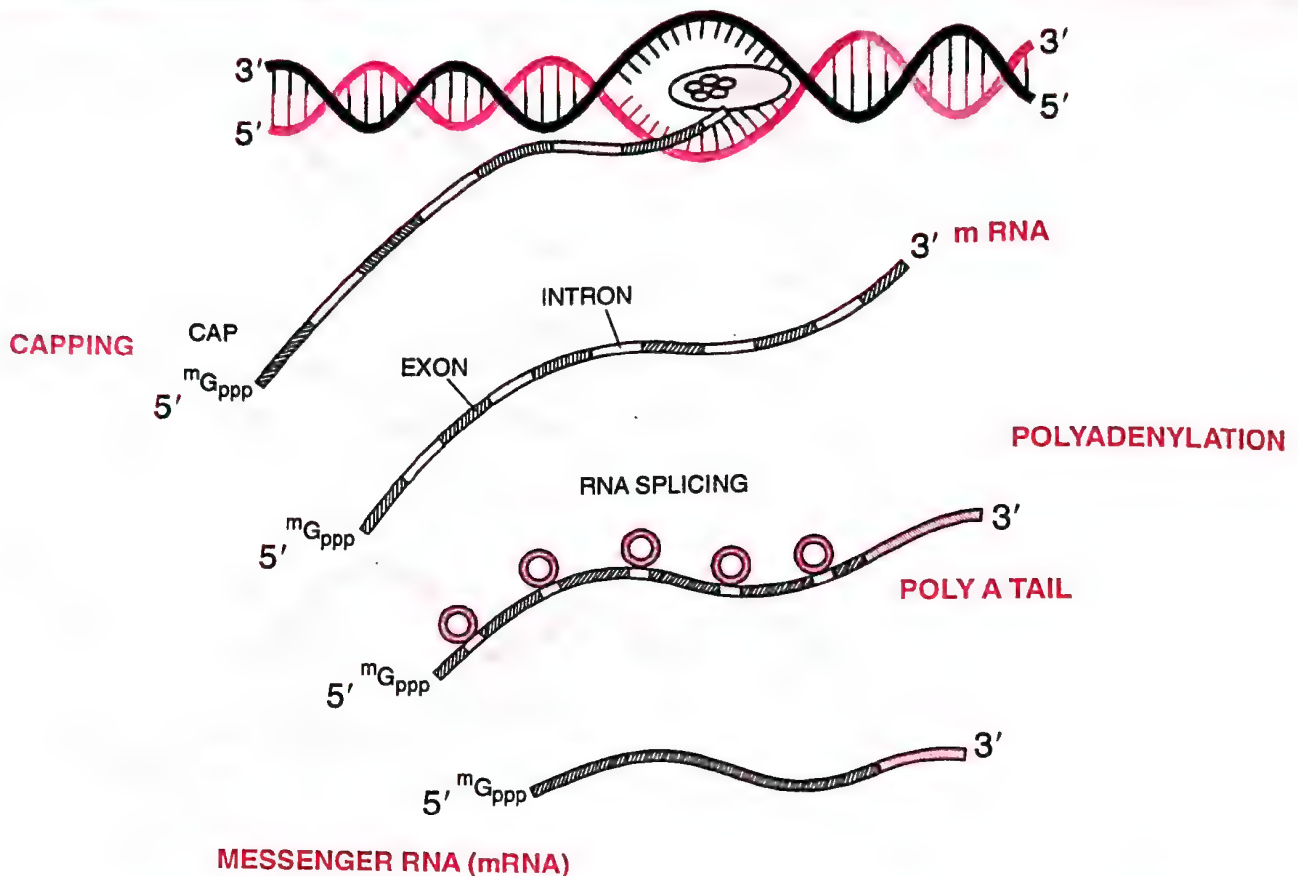


Fig. 6.26. Process of Transcription in Eukaryotes.

In eukaryotes, transcriptional unit has only one gene (monocistronic). Initiation of transcription requires proteins called **transcription factors**. A sigma factor is absent. No primer is required to start. RNAs are released and processed in the nucleus. Coupled transcription-translation is not possible in eukaryotes. Greater part of the products pass from the nucleus into the cytoplasm.

The nascent (newly formed) RNA synthesized by RNA polymerase II is called hnRNA or primary transcript. The primary transcript contains both unwanted base sequences (introns) alternated with useful base sequences (exons).

This primary transcript is converted into functional mRNA after post-transcriptional processing which involves 3 steps.

(i) **Capping at 5' end.** Capping at 5' end of hnRNA occurs shortly after the start of transcription. Addition of a **cap** to 5' end of hnRNA is called capping. This cap contains an unusual nucleotide (methyl guanosine triphosphate — abbreviated mGppp). The methylated cap protects the mRNA (developed from hnRNA) from degradation by nucleases. It also provides a ribosome binding site.

(ii) **Tailing at 3' end (Polyadenylation).** Tailing or polydenylation is addition of a poly adenate residues (about 200-300). Polyadenylation is thought to protect the 3' end from degradation by exonucleases.

(iii) **Splicing.** Splicing is the process of removal of introns through cutting and joining of exons in a defined order. Introns are removed with the help of **snRNPs** (pronounced as

snups). The snRNPs are formed by association of proteins with small nuclear RNAs (snRNAs). The ends of the adjacent exons are joined together by **ligase** enzyme.

The fully processed hnRNA is now called mRNA and is released from the nucleus into the cytoplasm for translation. The split-gene arrangements represent probably an ancient feature of genome. The presence of introns is reminiscent* of antiquity** and the process of splicing represents the dominance of **RNA-world**.

In vitro synthesis of RNA was first performed by Ochoa. He got Nobel Prize in 1959 for *in vitro* synthesis of RNA, alongwith Kornberg (for *in vitro* synthesis of DNA).

Differences between Prokaryotic and Eukaryotic Transcription

<i>Prokaryotic Transcription</i>	<i>Eukaryotic Transcription</i>
<ol style="list-style-type: none"> 1. It occurs in contact with cytoplasm. 2. There is no specific period for its occurrence. 3. Processing of released RNA occurs in cytoplasm. 4. It is coupled to translation. 5. There is one polymerase. 6. RNA polymerase has a sigma factor which separates at the time of transcription. 7. Transcriptional unit has one or more genes (polycistronic). 8. Products of transcription become effective <i>in situ</i> (in the original position). 9. Splicing is generally not required. 	<ol style="list-style-type: none"> 1. It occurs inside the nucleus. 2. Major part of transcription occurs in G₁ and G₂ phases. 3. Processing occurs inside the nucleus. 4. Transcription and translation are spacially separate. 5. There are three types of polymerases. 6. There are distinct transcription factors. A sigma factor is absent. 7. Transitional unit has only one gene. 8. Products of transcription come out of the nucleus for functioning in cytoplasm. 9. In most of the cases splicing is required for removing introns.

Differences Between Replication and Transcription

<i>Replication</i>	<i>Transcription</i>
<ol style="list-style-type: none"> 1. Replication is synthesis of DNA from DNA. 2. Both the strands take part in replication. 3. It produces double stranded replicas of DNA. 4. The whole duplex unwinds and the two strands separate throughout the length of DNA molecule. 5. The template remains hydrogen bonded to its product to form new replica. 6. RNA primer is essential for initiation. 7. The raw materials are four deoxyribonucleoside triphosphates, viz., dATP, dGTP, dCTP and dTTP. 8. It is catalysed by DNA polymerase III in procaryotes and DNA polymerase δ and ϵ in eukaryotes. 	<ol style="list-style-type: none"> 1. Transcription is synthesis of RNA from DNA. 2. Only one strand functions as template. 3. It forms single stranded RNAs. 4. Only a small part of DNA molecule unwinds for separating segments of DNA strands. 5. The transcribed strand separates from its template after its formation. 6. A primer is not required. 7. The raw materials are four ribonucleoside triphosphates, viz., ATP, GTP, CTP and UTP. 8. It is catalysed by RNA polymerase (one in prokaryotes and three in eukaryotes).

* Reminding you of something.

** Ancient times.

- | | |
|-----------------------------------------------------|------------------------------------------------------------------------------------|
| 9. It produces same types of DNA molecules. | 9. It forms three or more types of RNA molecules. |
| 10. Splicing is not required. | 10. Removal of noncoding components is required in a number of cases. |
| 11. It multiplies and conserves the genome. | 11. It produces working copies for forming cellular structure and its functioning. |
| 12. Only telomeric ends are synthesised separately. | 12. A lot of processing and modifications occur after transcription. |
| 13. Products do not degrade. | 13. Products usually degrade after their functioning is over. |
| 14. It occurs during S-phase of cell cycle. | 14. It occurs during G ₁ and G ₂ phases of cell cycle. |

RNA or Ribonucleic Acid (Fig. 6.27)

RNA or ribonucleic acid is a single chain polyribonucleotide which functions as carrier of coded genetic or hereditary information from DNA to cytoplasm for taking part in protein and enzyme synthesis. At places RNA may appear partially double stranded due to folding or coiling of the single strand (Fig 6.28). It contains 70-12000 ribonucleotides joined end to end. The axis or back bone is formed of alternate residues of phosphate and ribose sugar. Phosphate combines with carbon 5' of its sugar and carbon 3' of next sugar similar to the arrangement found in DNA strand. Nitrogen bases are attached to sugars at carbon 1' of the latter. There are four types of nitrogen bases—adenine (A), guanine (G, both purines), cytosine (C) and uracil (U, both pyrimidines). Nitrogen bases can be arranged in any sequence but the same is complementary to their sequence on DNA template. For example, a sequence of ATACTG of DNA template shall appear as UAUGAC over RNA. There are six types of RNAs—ribosomal, transfer, messenger, genomic (genetic), small nuclear and small cytoplasmic. Out of these the first three (rRNA, mRNA and tRNA) are major classes of RNAs that are involved in gene expression. RNA is **genomic** (genetic) in some viruses like TMV, HIV influenza virus etc. It is **double stranded** in reoviruses, wound tumor virus, Rice Dwarf virus and Mycophages.

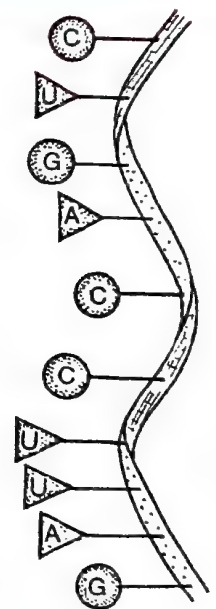


Fig. 6.27. Diagrammatic structure of RNA.

1. Ribosomal RNA (rRNA). It is the most abundant RNA (70-80% of total) which has 3-4 types. Some of its types (23S, 28S) are the longest of all RNAs. As the name indicates, rRNA is a constituent of ribosomes. Here it lies coiled in between and over the protein molecules. Depending upon their sedimentation coefficient, rRNAs of eucaryotes are of four types — 28S, 18S, 5.8S and 5S. Procarvotic ribosomes have three types of rRNAs — 23S, 16S and 5S. 28S, 5.8S and 5S (23S and 5S in procaryotes) occur in larger subunit of ribosome while 18S (16 S in procaryotes) is found in smaller subunit of ribosome. rRNA is transcribed in the form of a longer chain of 45S in eucaryotes and 30S in procaryotes. In eucaryotic transcript the arrangement in 5' → 3' direction is 18S — 5.8S — 28S. Several methylations occur prior to removal of spacer RNA. Removal of spacer RNA breaks the transcript into 2-3 parts. 5S is often transcribed separately.

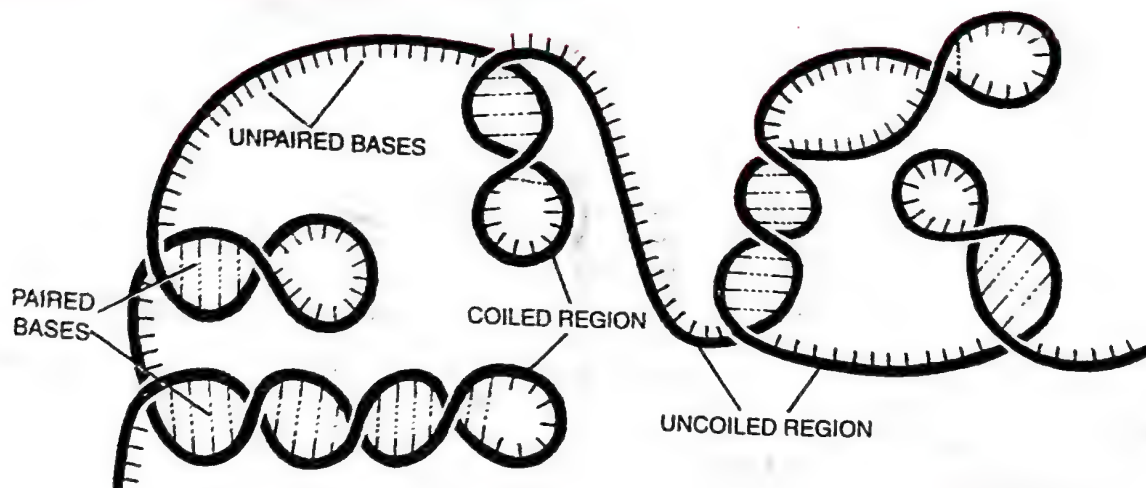


Fig. 6.28. Structure of rRNA (Schematic).

Functions. (i) rRNAs bind protein molecules and give rise to ribosomes. (ii) 3' end of 18S rRNA (16S in procaryotes) has nucleotides complementary to those of cap region of mRNA. (iii) 5S rRNA and surrounding protein complex provide binding site for tRNA. (iv) rRNAs get associated with specific proteins to form ribosome subunits. 50S subunit of prokaryotic ribosome contains 23S rRNA, 5S rRNA and some 32 protein molecules. 30S subunit of prokaryotic ribosome has 16S rRNA and about 21 protein molecules. 60S subunit of eukaryotic ribosome contains 28S rRNA, 5S rRNA, 5.8S rRNA and about 50 protein molecules. 40S subunit of eukaryotic ribosome consists of 18S rRNA and some 33 protein molecules (Fig. 6.29).

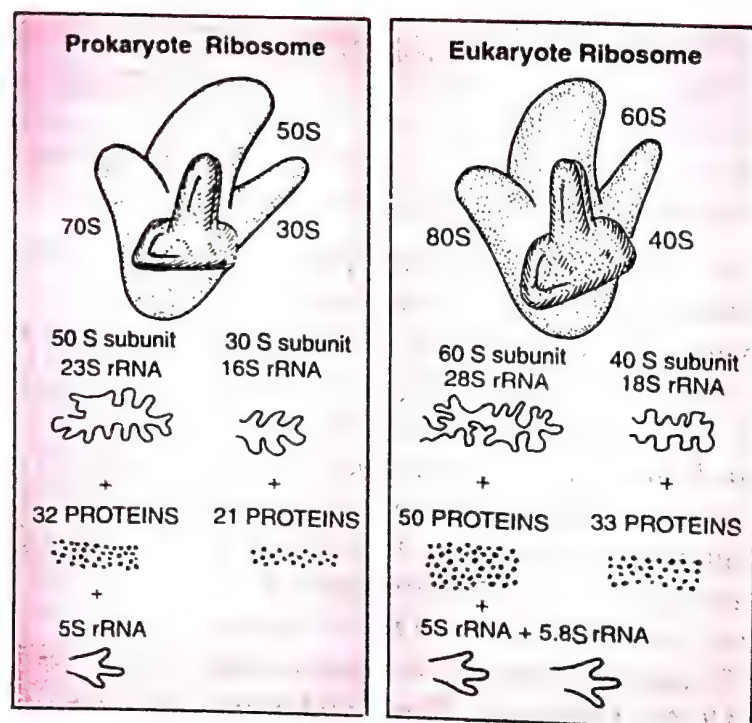


Fig. 6.29. Generalized structure of ribosome in prokaryotes and eukaryotes.

2. Transfer RNA (tRNA) —

The Adaptive Molecule. It is also called **soluble** or **sRNA** in which form it was known before the discovery of genetic code. There are over 100 types of tRNAs. Transfer RNA constitutes about 15% of the total RNA. tRNA is the smallest RNA with 73-93

nucleotides and sedimentation coefficient of 4S. The nitrogen bases of several of its nucleotides get modified, *e.g.*, pseudouridine (ψ), dihydrouridine (DHU), inosine (I) ribo-thymidine (rT). This causes coiling of the otherwise single-stranded tRNA into L-shaped form (three dimensional, Klug, 1974) or clover-like form (two dimensional, Holley, 1965). About half

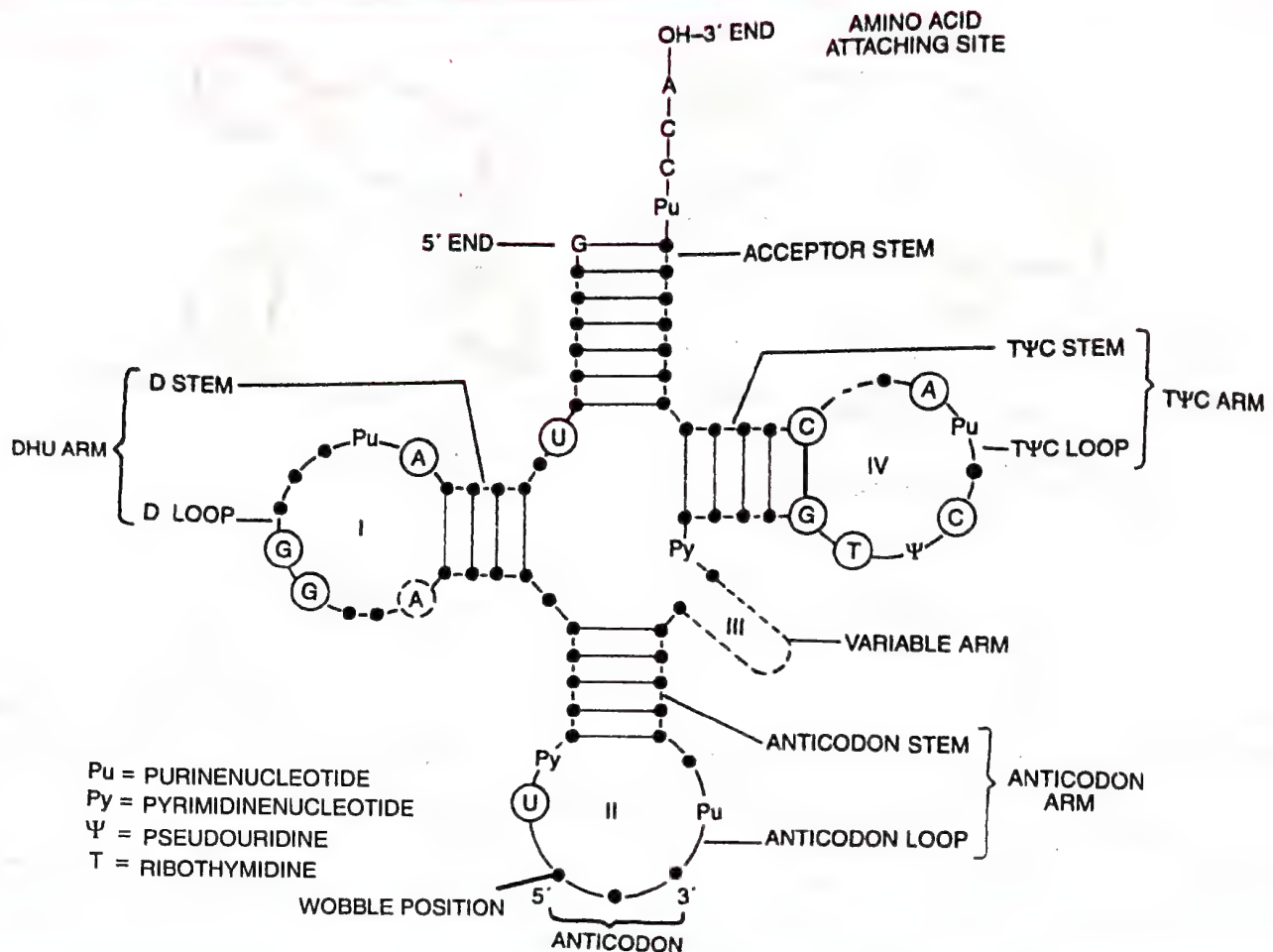


Fig. 6.30. Clover leaf model of tRNA.

of the nucleotides are base paired to produce paired stems. Five regions are unpaired or single stranded — AA-binding site, TΨC loop, DHU loop, extra arm and anticodon loop. (i) **Anticodon Loop**. It has 7 bases out of which three bases form anticodon (codon) for recognising and attaching to the codon of mRNA. (ii) **AA-Binding Site**. It is amino acid binding site. The site lies at the 3' end opposite the anticodon and has CCA—OH group. The 5' end bears G. Amino acid or AA-binding site and anticodon are the two **recognition sites** of tRNA. (iii) **TΨC Loop**. It has 7 bases out of which Ψ (pseudouridine) and rT (ribothymidine) are unusual bases. The loop is the site for attaching to ribosome. (iv) **DHU Loop**. The loop contains 8–12 bases. It is largest loop and has dihydrouridine. It is binding site for aminoacyl synthetase enzyme. (v) **Extra Arm**. It is a variable side arm or loop which lies between TΨC loop and anticodon. It is not present in all tRNAs. The exact role of extra arm is not known.

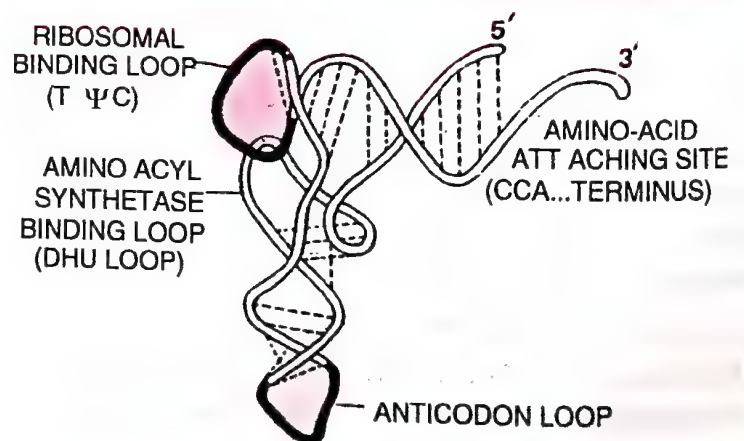


Fig. 6.31. L-form model of tRNA.

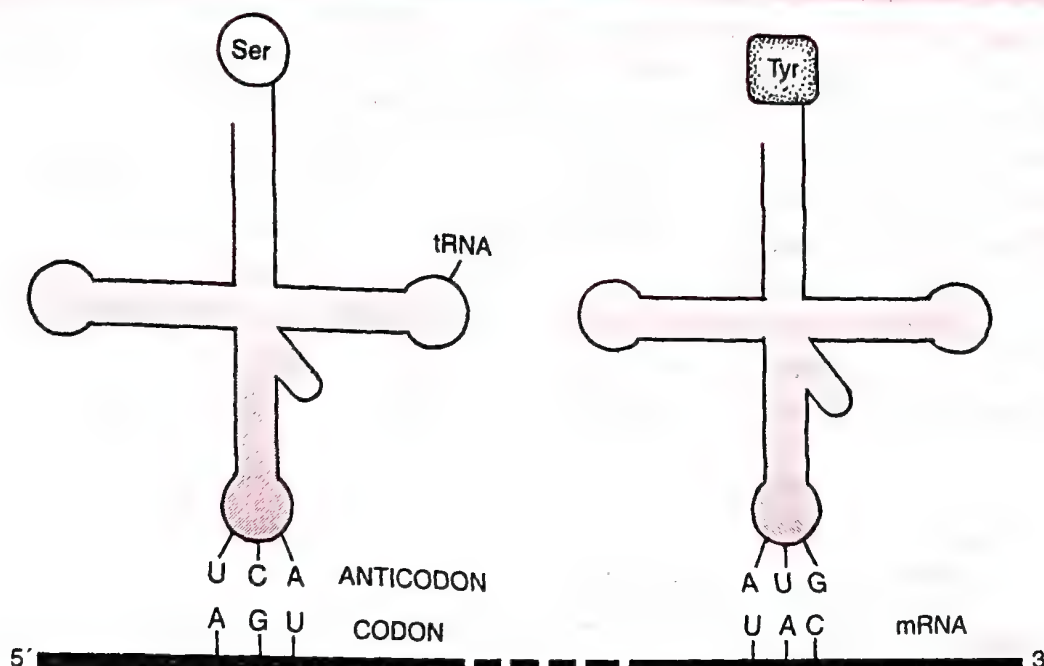


Fig. 6.32. tRNA — the adapter molecule.

Functions. (i) As first postulated by Crick, tRNA is **adapter molecule** which is meant for transferring amino acids to ribosomes for synthesis of polypeptides. There are different tRNAs for different amino acids. Some amino acids can be picked up by 2—6 tRNAs. tRNAs place specific amino acids at particular points during polypeptide synthesis as per codons of mRNA. Codons are recognised by anticodons of tRNAs. Specific amino acids are recognised by particular activating or aminoacyl synthetase enzymes. (ii) They hold peptidyl chains over the mRNAs. (iii) The initiator tRNA has the dual function of initiation of protein synthesis as well as bringing in of the first amino acid. There is, however, no tRNA for stop signals.

Differences between Codon and Anticodon	
Codon	Anticodon
<ol style="list-style-type: none"> 1. It is found in DNA and mRNA. 2. Codon is complementary to a triplet of template strand. 3. It determines the position of an amino acid in a polypeptide. 	<ol style="list-style-type: none"> 1. It occurs in tRNA. 2. It is complementary to a codon. 3. It helps in bringing a particular amino acid at its proper position during translation.

3. Messenger RNA (mRNA). It is a long RNA which constitutes 2—5% of the total RNA content of the cell. It brings instructions from the DNA for the formation of particular type of polypeptide. mRNA is, therefore, also called **informational** or **genetic RNA**. The instructions are present in the base sequence of its nucleotides. It is called **genetic code**. Three adjacent nitrogen bases specify a particular amino acid. Formation of polypeptide occurs over the ribosome. mRNA gets attached to ribosome. tRNAs are induced to bring amino acids in a particular sequence according to the sequence of codons present over mRNA. In eukaryotes mRNA has methylated (7-MeG) region at the 5' terminus. It functions as a **cap** for attachment with ribosome. A Shine-Delgarno sequence is, instead, present in

prokaryotes. Cap is followed by an **initiation codon** (AUG) either immediately or after a small noncoding leader region. Then there is coding region followed by **termination codon** (UAA, UAG, or UGA). After termination codon there is a small noncoding trailer region and poly A area or **tail** at the 3' terminus (Fig. 6.33). Both cap and tail protect mRNA from enzymic breakdown. The leader and trailer regions are called **UTR** (Untranslated regions). An mRNA may specify only a single polypeptide or a number of them. The former is called **monocistronic** while the latter is known as **polycistronic**. Polycistronic mRNA is more common in prokaryotes. Eukaryotic mRNA is usually monocistronic. The life time of mRNA is also variable. In some lower forms it is from a few minutes to a few hours. On the other hand the mRNAs of higher forms seem to have a long life. It is several days in case of young red blood corpuscles which continue to form haemoglobin even when nucleus has degenerated.

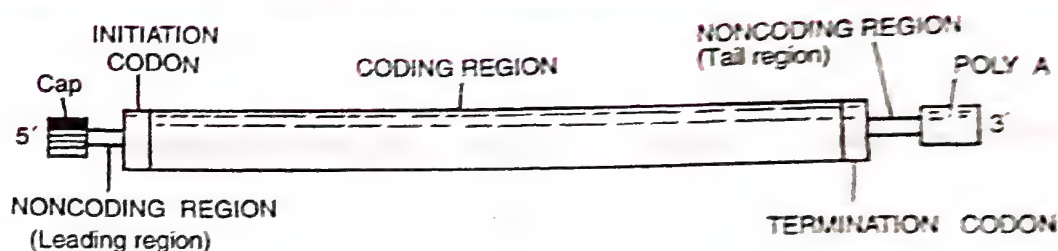


Fig. 6.33. Parts of an mRNA strand.

Functions. (i) mRNA carries coded information for translation into polypeptide formation. (ii) Through reverse transcription it can form compact genes which are used in genetic engineering. The phenomenon also occurs in nature and has added certain genes in the genomes. (iii) It has a cap region for attachment to ribosome. (iv) Cap protects the mRNA from degradation from enzymes. (v) mRNA has a tail region for protection from cellular enzymes and detachment from ribosome.

Differences between Initiation Codons and Termination Codons

Initiation Codons	Termination Codons
1. These codons are found at 5' end of mRNA.	1. These are found at 3' end of mRNA.
2. Mostly AUG (occasionally, GUG, UUG or CUG) is the initiation codon.	2. UAA, UAG and UGA are three terminal codons and only one is present at 3' end.
3. It starts the initiation of protein synthesis.	3. It stops the process of protein synthesis.

Comparison between messenger, ribosomal and transfer RNAs

mRNA	rRNA	tRNA
1. It accounts for about 5% of total RNA in the cell.	It accounts for about 80% of total RNA in the cell.	It accounts for about 15% of total RNA in the cell.
2. It consists of 75-6000 bases.	It consists of 100-5000 bases.	It consists of 73-93 bases.
3. Its mol. wt. 25000-2000000 daltons.	It mol. wt. 35000-1800000 daltons.	Its mol. wt. is about 25000 daltons.
4. Its sedimentation coefficient is 6-30 S.	Its sedimentation coefficient is 5S, 5.8S, 28S and 18S in eukaryotes; 5S, 16S and 23S in prokaryotes.	Its sedimentation coefficient is 4S.

5. It is moderate to large sized with moderate to maximum mol. weight but is least abundant.	It is smaller; moderate to large sized which is most abundant and highly coiled.	It is smallest and coiled like a clover leaf.
6. It carries a coding message for many amino acids.	It carries no coding message.	It carries coding message for only one amino acid.
7. It is linear and never coiled.	It is linear and coiled.	It is folded.
8. It is synthesized by RNA polymerase II in nucleus.	Its synthesis occurs in nucleolus by RNA polymerase I.	It is synthesized by RNA polymerase III in nucleus.
9. It has no modification of bases in coding region.	Modification of bases is very less.	About 5% bases are modified.
10. It is of various types depending upon number of genes.	It is of 3 or 4 types.	It is of about 100 types.
11. It is short lived (3 seconds to few days) and commonly degrades after protein synthesis.	It is most stable, used again and again and does not degrade.	It is quite stable, used again and again, degrades very slowly.
12. It is called template/nuclear/ messenger or informational RNA as it carries genetic information provided by DNA.	It is called insoluble RNA and forms ribosomes.	It is called soluble or adapter RNA and carries amino acids to mRNA during protein synthesis.

4. **Genomic RNA** (Genetic RNA). It is found in some viruses called riboviruses. Genomic RNA may be single stranded (e.g., Tobacco Mosaic Virus or TMV) or double stranded (e.g., Reovirus). It is fragmented in influenza virus. Genomic RNA acts as a hereditary material. It may replicate directly, or form DNA in the host cell to produce RNA of its own type.

5. **Catalytic RNAs**. Cech *et al* (1981) found catalytic activity (cleavage and covalent bond formation) in RNA precursor of ciliated protozoan called *Tetrahymena thermophila*. It was called **ribozyme**. In 1983, Altman *et al* discovered that ribonuclease - P that takes part in processing tRNA from its precursor is a biocatalyst made of RNA and protein. Noller *et al* (1992) found peptidyl transferase to be RNA enzyme.

6. **Small Nuclear RNA** (snRNA). It is a small sized RNA present in the nucleus. Each RNA is combined with 7—8 molecules of proteins to form small nuclear ribonucleoprotein or snRNP. SnRNA takes part in splicing (U1 and U2), rRNA processing (U3) and mRNA processing (U7).

7. **Small Cytoplasmic RNA** (scRNA). It is small sized RNA occurring free in the cytoplasm. One such small cytoplasmic RNA is 7S and combines with 6 protein molecules to produce **signal recognition particle** or SRP. The latter helps in taking and binding a ribosome to endoplasmic reticulum for producing secretory proteins.

8. **RNA Interference (RNAi)**. It is involved in regulating gene expression. **Micro RNAs** (miRNAs) are 21-22 bp long RNAs which attach to complementary parts of mRNAs and bring about their degeneration. **Short interfering RNAs** (siRNAs) are double stranded 19-23 bp long RNAs which also do the same job. They become single stranded and form RISC (RNA induced silencing complex) after combining with proteins.

Differences Between DNA and RNA

DNA	RNA
<ol style="list-style-type: none"> 1. It usually occurs inside nucleus and some cell organelles. 2. DNA is the genetic material. 3. It is double stranded with the exception of some viruses (e.g., $\phi \times 174$). 4. DNA contains over a million nucleotides. 5. Molecular weight ranges from 3-4 million in <i>Escherichia coli</i> to 263 million in chromosome 1 of human beings. 6. It is Fuelgen positive. 7. DNA is of only two types; intra-nuclear and extra-nuclear. 8. It contains deoxyribose sugar. 9. Nitrogen base thymine occurs in DNA alongwith three others — adenine, cytosine and guanine. 10. Unusual bases are very few or absent. 11. Renaturation after melting is slow. 12. Hydrogen bonds are formed between complementary nitrogen bases of the opposite strands of DNA (A – T, C – G). 13. DNA is spirally twisted to produce a regular helix. 14. It replicates to form new DNA molecules. 15. DNA replication requires a primer. 16. DNA transcribes genetic information to RNA. 17. Its quantity is fixed for cell. 18. DNA controls metabolism and genetics including variations. 19. Purine and pyrimidine bases are in equal number. 20. It occurs in the form of prochromosome, chromatin or chromosomes. 21. ^3H precursor is ^3H-thymidine. 22. It is long lived. 23. It can be hydrolysed by DNA-ase. 	<ol style="list-style-type: none"> 1. Very little RNA occurs inside nucleus. Most of it is found in the cytoplasm. 2. RNA is not the genetic material except in certain viruses, e.g., <i>Reovirus</i>. 3. RNA is single stranded with the exception of some viruses (e.g., double stranded in <i>Reovirus</i>). 4. Depending upon the type, RNA contains 70-12000 nucleotides. 5. Molecular weight ranges from 25000-2,000,000. 6. RNA is Fuelgen negative. 7. There are at least three types of RNAs — mRNA, rRNA and tRNA. 8. It contains ribose sugar. 9. Thymine is replaced by uracil in RNA. The other three are similar — adenine, cytosine and guanine. 10. Many unusual or modified bases are often present. 11. It is quite fast. 12. Base pairing through hydrogen bonds occurs only in the coiled parts. 13. The strand may get folded at places to produce a secondary helix or pseudohelix. 14. It cannot normally replicate itself. 15. No primer is needed during the formation of RNA. 16. RNA translates the transcribed message for forming polypeptides. 17. The quantity of RNA of a cell is variable. 18. It only controls metabolism under instructions from DNA. 19. There is no proportionality between number of purines and pyrimidine bases. 20. It occurs in ribosomes or forms association with ribosomes. 21. ^3H precursor is ^3H-uridine. 22. Some RNAs are very short lived while others have somewhat longer life. 23. It is hydrolysed by RNA-ase.

GENETIC CODE

Though DNA is made up of only four types of nucleotides, the latter can be positioned in countless ways. Thus a DNA chain of only ten nucleotide length can have 4^{10} or 1,048,576 types of strands. As a single DNA molecule has several thousand nucleotides, a limitless specificity can be incorporated in the DNA.

There is an intimate connection between genes and synthesis of polypeptides or enzymes. In modern terminology a gene refers to a cistron of DNA. A cistron is made of a large number of nucleotides. Arrangement of nucleotides or their nitrogen bases is connected with the synthesis of proteins by influencing the incorporation of amino acids in them. *The relationship between the sequence of amino acids in a polypeptide and nucleotide sequence of DNA or mRNA is called genetic code.* There is one problem. DNA contains only four types of nitrogen bases or nucleotides while the number of amino acids is 20. It was, therefore, hypothesised by George Gamow, a physicist, that **triplet code** (consisting of three adjacent bases for one amino acid) is operative. A number of researches have contributed in deciphering the genetic code in 1960s, e.g., Francis H.C. Crick, Severo Ochoa, Marshal W. Nirenberg, Hargobind Khorana and J.H. Matthaei. Severo Ochoa discovered polynucleotide phosphorylase which could polymerise ribonucleotides to produce RNA without any template. Hargobind Khorana developed the technique of synthesising RNA molecules with well defined combination of bases (homopolymers and copolymers). Marshall Nirenberg found out the method of protein synthesis in cell free systems. In 1968 Nobel Prize was awarded to Holley, Nirenberg and Khorana for their work on genetic code and its working. The different researches which helped in deciphering the triplet genetic code are as follows :

1. Crick *et al* (1961) observed that deletion or addition of one or two base pairs in DNA of T₄ bacteriophage disturbed normal DNA functioning. However, when three base pairs were added or deleted the disturbance was minimum.

2. Nirenberg and Matthaei (1961) argued that a singlet code (one amino acid specified by one nitrogen base) can specify only 4 acids (4^1), a doublet code only 16 (4^2) while a triplet code can specify upto 64 amino acids (4^3). As there are 20 amino acids, a triplet code (three nitrogen bases for one amino acid) can be operative.

3. Nirenberg (1961) prepared polymers of the four nucleotides – UUUUUU..... (Polyuridylic acid), CCCCCC... (polycytidylic acid), AAAAAA... (polyadenylic acid) and GGGGGG... (polyguanylic acid). He observed that poly-U stimulated the formation of polyphenylalanine, poly-C of polyproline while poly-A helped form polylysine. However, poly-G did not function (it formed triple-stranded structure which does not function in translation). Later on, GGG was found to code for amino acid glycine.

4. Khorana (1964) synthesised copolymers of nucleotides like UGUGUGUG.. and observed that they stimulated the formation of polypeptides having alternately similar amino acids as cysteine - valine - cysteine. This is possible only if three adjacent nucleotides specify one amino acid (e.g., UGU) and other three the second amino acid (e.g., GUG).

GUG	UGU	GUG	UGU	GUG
Val	— Cys	— Val	— Cys	— Val

5. The triplet codons were confirmed by *in vivo* codon assignment through (i) amino acid replacement studies (ii) frame shift mutations.

6. Slowly all the codons were worked out (Table 6.1). Some amino acids are specified by more than one codon. The code languages of DNA and mRNA are complementary. Thus the two codons for phenylalanine are UUU and UUC in case of mRNA while they are AAA and AAG for DNA. Normally genetic code represents **mRNA language**. This is because the cytoplasmic constituents can read the code from mRNA and not the DNA present inside the nucleus.

Table 6.1. Assignment of mRNA codons to Amino Acids

		SECOND BASE					
		U	C	A	G		
FIRST BASE	U	UUU } Phe	UCU } Ser	UAU } Tyr	UGU } Cys	U	THIRD BASE
		UUC } Phe	UCC } Ser	UAC } Tyr	UGC } Cys	C	
		UUA } Leu	UCA } Ser	UAA } Stop (ochre)	UGA } Stop (opal)	A	
		UUG } Leu	UCG } Ser	UAG } Stop (amber)	UGG } Trp	G	
	C	CUU } Leu	CCU } Pro	CAU } His	CGU } Arg	U	
		CUC } Leu	CCC } Pro	CAC } His	CGC } Arg	C	
		CUA } Leu	CCA } Pro	CAA } Gln	CGA } Arg	A	
		CUG } Leu	CCG } Pro	CAG } Gln	CGG } Arg	G	
	A	AUU } Ile	ACU } Thr	AAU } Asn	AGU } Ser	U	
		AUC } Ile	ACC } Thr	AAC } Asn	AGC } Ser	C	
		AUA } Met or start	ACA } Thr	AAA } Lys	AGA } Arg	A	
		AUG } Met or start	ACG } Thr	AAG } Lys	AGG } Arg	G	
	G	GUU } Val	GCU } Ala	GAU } Asp	GGU } Gly	U	
		GUC } Val	GCC } Ala	GAC } Asp	GGC } Gly	C	
		GUA } Val	GCA } Ala	GAA } Glu	GGA } Gly	A	
		GUG } Val	GCG } Ala	GAG } Glu	GGG } Gly	G	

Salient Features of Genetic Code

1. **Triplet Code.** Three adjacent nitrogen bases constitute a codon which specifies the placement of one amino acid in a polypeptide.

2. **Start Signal.** Polypeptide synthesis is signalled by two **initiation codons** — commonly AUG or methionine codon and rarely GUG or valine codon. They have dual functions.

3. **Stop Signal.** Polypeptide chain termination is signalled by three **termination codons** — UAA (ochre), UAG (amber) and UGA (opal). They do not specify any amino acid and are hence also called **nonsense codons**. However, UGA also encodes for amino acid — **selenocysteine** found in some proteins and enzymes in humans (Back *et al*, 1991).

4. **Universal Code.** The genetic code is applicable universally, *i.e.*, a codon specifies the same amino acid from a virus to a tree or human being. Thus mRNA from chick oviduct introduced in *Escherichia coli* produces ovalbumen in the bacterium exactly similar to one formed in chick.

5. **Nonambiguous Codons.** One codon specifies only one amino acid and not any other.
6. **Related Codons.** Amino acids with similar properties have related codons, e.g., aromatic amino acids tryptophan (UGG), phenylalanine (UUC, UUU), tyrosine (UAC, UAU).
7. **Commaless.** The genetic code is continuous and does not possess pauses after the triplets. If a nucleotide is deleted or added, the whole genetic code will read differently. Thus a polypeptide having 50 amino acids shall be specified by a linear sequence of 150 nucleotides. If a nucleotide is added or deleted in the middle of this sequence, the first 25 amino acids of polypeptide will be same but next 25 amino acids will be quite different.
8. **Polarity.** Genetic code has a polarity. Code of mRNA is read from 5' → 3' direction.
9. **Non-overlapping Code.** A nitrogen base is specified by only one codon.
10. **Degeneracy of Code.** Since there are 64 triplet codons and only 20 amino acids, the incorporation of some amino acids must be influenced by more than one codon. Only tryptophan (UGG) and methionine (AUG) are specified by single codons. All other amino acids are specified by two (e.g., phenylalanine — UUU, UUC) to six (e.g., arginine—CGU, CGC, CGA, CGG, AGA, AGG) codons. The latter are called **degenerate** or **redundant** codons. In degenerate codons, generally the first two nitrogen bases are similar while the third one is different. As the third nitrogen base has no effect on coding, the same is called **wobble position** (Wobble hypothesis; Crick, 1966).
11. **Colinearity.** Both polypeptide and DNA or mRNA have a linear arrangement of their components. Further, the sequence of triplet nucleotide bases in DNA or mRNA corresponds to the sequence of amino acids in the polypeptide manufactured under the guidance of the former. Change in codon sequence also produces a similar change in amino acid sequence of polypeptide.
12. **Cistron-Polypeptide Parity.** Portion of DNA called cistron (=gene) specifies the formation of a particular polypeptide. It means that the genetic system should have as many cistrons (=genes) as the types of polypeptides found in the organism.

Exceptions

1. **Different Codons.** In *Paramecium* and some other ciliates termination codons UAA and UGA code for glutamine.
2. **Overlapping Genes.** $\phi \times 174$ has 5375 nucleotides that code for 10 proteins which require more than 6000 bases. Three of its genes E, B and K overlap other genes. Nucleotide sequence at the beginning of E gene is contained within gene D. Likewise gene K overlaps with genes A and C. A similar condition is found in SV-40.
3. **Mitochondrial Genes.** AGG and AGA code for arginine but function as stop signals in human mitochondrion. UGA, a termination codon, corresponds to tryptophan while AUA (codon for isoleucine) denotes methionine in human mitochondria.

Master Copy

DNA is called the **master copy** of genetic information because it is not directly involved in the expression of genetic traits. DNA is preserved. It replicates only when a new master copy is to be formed. Normally it produces **working copies** in the form of mRNAs. The latter pass out in the cytoplasm to guide the synthesis of polypeptides.

Mutations and Genetic Code

The relationship between genes and DNA are best understood by mutation studies. Effects of large deletions and rearrangements in a segment of DNA are easy to comprehend. It may result in loss or gain of a gene and so a function. A classical example of gene mutation

or point mutation is a change of single base pair in the gene for beta globin chain that results in the change of amino acid residue glutamate to valine. It results into a diseased condition called as **sickle cell anemia**. Insertion or deletion of one or two bases changes the reading frame from the point of insertion or deletion. Insertion or deletion of three or its multiple bases insert or delete one or multiple codon hence one or multiple amino acids, and reading frame remains unaltered from that point onwards. Such mutations are referred to as frame shift mutations. This forms the genetic basis of proof that codon is a triplet and it is read in a contiguous manner.

TRANSLATION (Protein Synthesis)

Translation Machinery

It consists of ribosomes, amino acids, mRNA, tRNAs and amino acyl tRNA synthetases. mRNA functions as a template having genetic information. Ribosome is the site of protein synthesis. tRNA brings the desired amino acid, reads the genetic information and places the amino acid at proper place. RNAs are formed over DNA during transcription while protein synthesis occurs in the cytoplasm over ribosomes. The two are separated both in space and time. It prevents the intermixing of raw materials, protects DNA from respiratory enzymes and ribosomal machinery from nucleases.

1. **Ribosomes** (Fig. 6.34). Protein synthesis occurs over the ribosomes. Ribosomes are, therefore, also called **protein factories**. Each ribosome has two unequal parts, small and large. The larger subunit of ribosome has a groove for pushing out the newly formed polypeptide and protecting the same from cellular enzymes. The smaller subunit fits over the larger one like a cap but leaves a tunnel for mRNA. The two subunits come together only at the time of protein formation. The phenomenon is called **association**. Mg^{2+} is essential for it. Soon after the completion of protein synthesis, the subunits separate. The phenomenon is called **dissociation**.

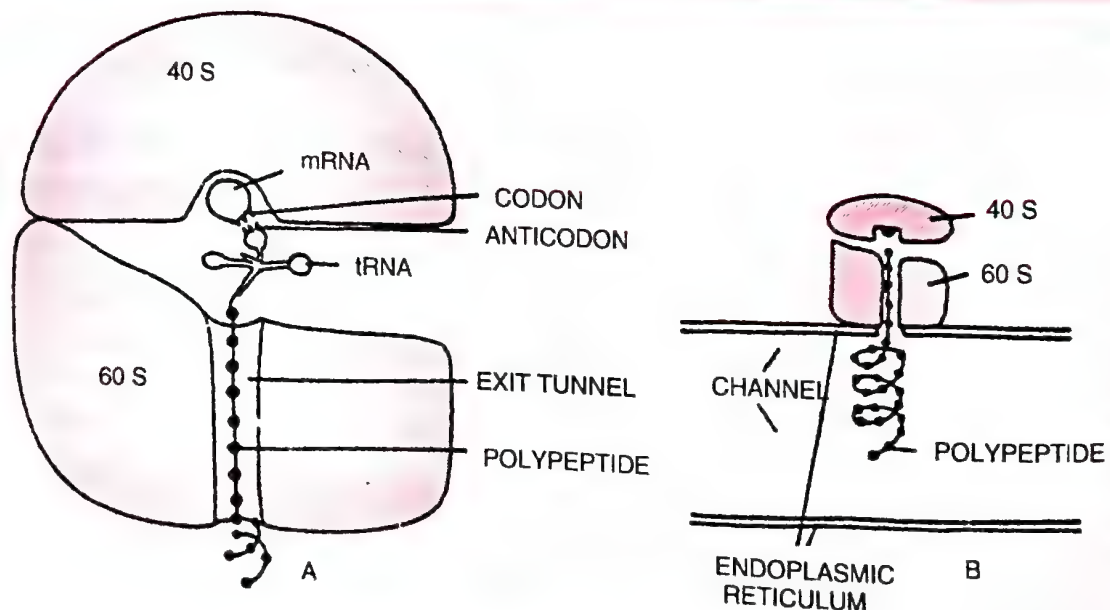


Fig. 6.34. Ribosomes as protein factory. A, relationship between the various components. B, synthesis of polypeptide on ribosome connected with endoplasmic reticulum.

Ribosomes usually form rosette or helical groups during active protein synthesis. They are known as **polyribosomes** or **polysomes** (Rich, 1963). The different ribosomes of a

polysome are held together by a strand of messenger RNA. Polyribosome helps to produce a number of copies of the same polypeptide. The adjacent ribosomes of a polyribosome are about 340 Å or 34 nm apart. The different parts of a ribosome connected with protein synthesis are :

- (i) A channel for mRNA. It lies between the two subunits.
- (ii) An exit tunnel for passage of newly synthesised polypeptide. The tunnel is part of the larger subunit.
- (iii) There are three reactive sites—P (D), A and E (Fig 6.35). P-site (peptidyl transfer or donor site) is jointly contributed by the two ribosomal subunits. A-site (amino-acyl or acceptor site) is situated on the larger subunit of ribosome. It faces the tunnel between the two subunits. E or exit site is part of larger subunit facing the tunnel site.

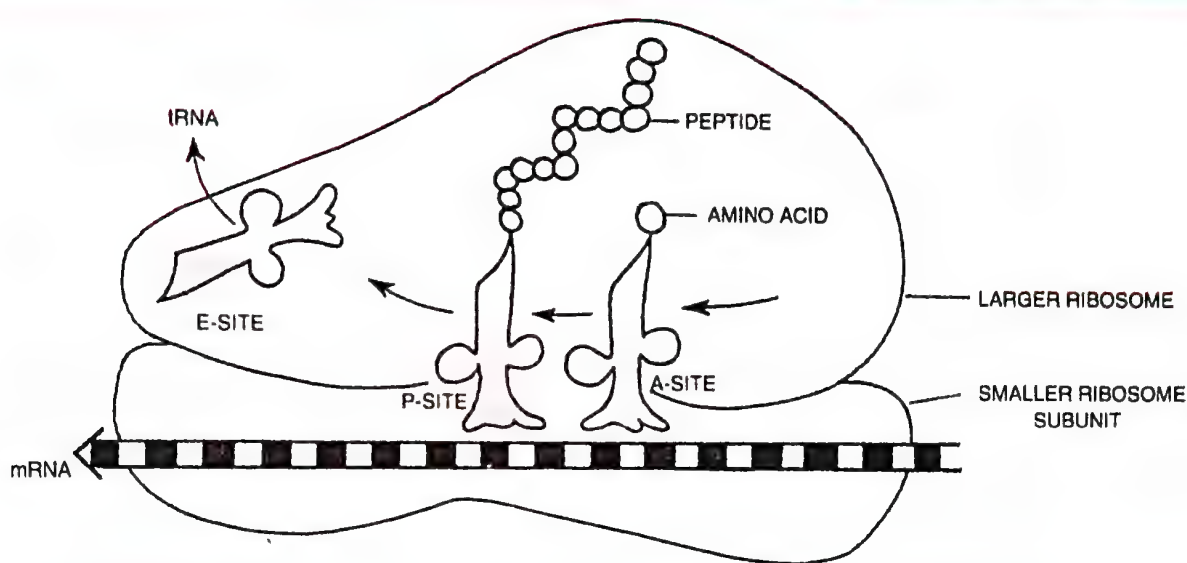


Fig. 6.35. Ribosome and Reactive Sites

(iv) Enzyme peptidyl transferase is a **ribozyme**. It is component of larger subunit of ribosome (23S rRNA in prokaryotes).

(v) Smaller subunit of ribosome has a point for recognising mRNA and binding area for initiation factors.

2. **Amino Acids.** Hundreds of different types of proteins may be manufactured in a single cell. All types of proteins are formed from the same amino acids. It is the arrangement of amino acids in the polypeptides and the number of the latter which provide specificity to the proteins. There are some 20 amino acids and amides which constitute building blocks or monomers of proteins. They occur in the **cellular pool**.

3. **mRNA.** It is messenger RNA which brings coded information from DNA and takes part in its translation by bringing amino acids in a particular sequence during the synthesis of polypeptide. However, the codons of mRNA are not recognised by amino acids but by anticodons of their adapter molecules (tRNAs → aa-tRNAs). Translation occurs over the ribosomes. The same mRNA may be reused time and again. In the form of polysome, it can help synthesise a number of copies simultaneously.

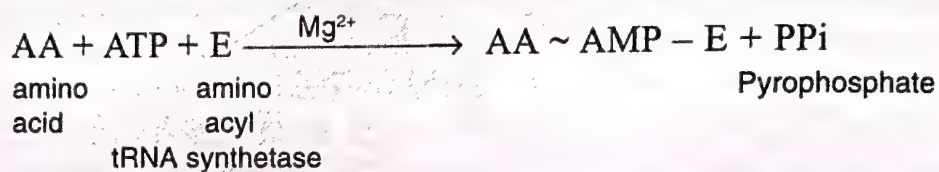
4. **tRNAs.** They are transfer or soluble RNAs which pick up particular amino acids (at CCA or 3' end) in the process called **charging**. The charged tRNAs take the same to mRNA over particular codons corresponding to their anticodons. A tRNA can pick up only a specific

amino acid though an amino acid can be specified by 2-6 tRNAs. Each tRNA has an area for coming in contact with ribosome (TΨC) and the enzyme amino acyl tRNA synthetase (DHU).

5. **Amino-Acyl tRNA-Synthetase.** It is the enzyme that helps in combining amino acid to its particular tRNA. The enzyme is specific for each amino acid. It is also called **aa-activating enzyme**.

Translation Mechanism (Figs. 6.36—37)

1. **Activation of Amino Acids.** It is carried out by **activating enzymes**, known as **aminoacyl tRNA synthetases** (Zamecnik and Hoagland, 1957). In the presence of ATP, an amino acid combines with its specific aminoacyl-tRNA synthetase. Mg^{2+} is required. It produces **amino-acyl-adenylate-enzyme complex**. The energy made available to amino acid during its activation is later used in formation of peptide bonds.

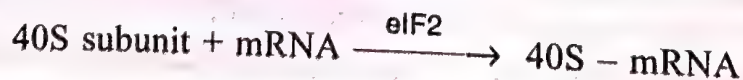


Hydrolysis of pyrophosphate with the help of enzyme pyrophosphatase provides energy for driving the initial reactions.

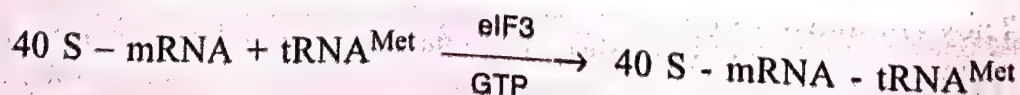
2. **Charging or Aminoacylation of tRNA.** The complex reacts with tRNA specific for the amino acid to form aminoacyl-tRNA complex. Enzyme and AMP are released. tRNA complexed with amino acid is sometimes called **charged tRNA**. The amino acid is linked to 3-OH-end of tRNA through its $-\text{COOH}$ group,



3. **Initiation.** It requires factors called **initiation factors**. There are three initiation factors in procaryotes — IF3, IF2 and IF1. Eucaryotes have nine initiation factors — eIF2, eIF3, eIF1, eIF4A, eIF4B, eIF4C, eIF4D, eIF5, eIF6. Out of these IF3 or eIF2 is attached to smaller subunit of ribosome in the dissociated state. GTP is required. mRNA attaches itself to smaller subunit of ribosome in the region of its cap. The cap has nucleotides complementary to the nucleotides present at the 3' end of rRNA. The attachment is such that initiation codon of mRNA (AUG or GUG) comes to lie at P-site. Initiation factor already present in smaller subunit catalyses the reaction (eIF2 in eucaryotes and IF3 in procaryotes).

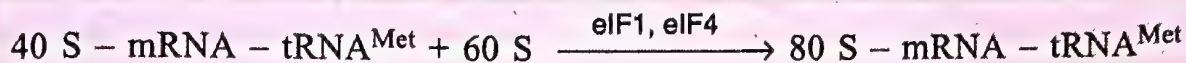


Aminoacyl tRNA complex specific for the initiation codon (methionine-tRNA or valine-tRNA) reaches the P-site (D-site). Anticodon (e.g., UAC of tRNA^{Met}) establishes temporary hydrogen bonds with the initiation codon (e.g., AUG) of mRNA. The codon-anticodon reaction occurs in the presence of initiation factor eIF3 in eucaryotes and IF2 in procaryotes. The step also requires energy which is provided by GTP.



The initiating methionine accepting tRNA is charged with non-formylated methionine (tRNA^{mMet}) in the cytoplasm of eucaryotes and formylated methionine (tRNA^{fMet}) in procaryotes, plastids and mitochondria. tRNA engaged in transferring formylated methionine is different than the one that transfers nonformylated methionine.

In the presence of Mg^{2+} , the larger subunit of ribosome now combines with 40S-mRNA-tRNA^{Met} complex to form intact ribosome. It requires initiation factor IF1 in procaryotes and factors eIF1, eIF4 (A, B, C) in eucaryotes. Coming together of the two subunits of ribosomes is called **association**. The intact ribosome encloses the mRNA-tRNA complex present at the P-site but keeps the A-site exposed.



4. **Elongation** (Polypeptide Chain Formation). An aminoacyl tRNA complex reaches the A-site and attaches to mRNA codon next to initiation codon with the help of its anticodon. The step requires GTP and an **elongation factor** (eEF1 in eucaryotes and EF-Tu as well EF-Ts in procaryotes). It has been found out that in *Escherichia coli* the most abundant protein is elongation factor (EF-Tu). A peptide bond ($-\text{CO}-\text{NH}-$) is established between the carboxyl group ($-\text{COOH}$) of amino acid attached to tRNA at P-site and amino group ($-\text{NH}_2$) of amino acid attached to tRNA at A-site. The reaction is catalysed by enzyme **peptidyl transferase** which is an RNA-enzyme. Due to this, NH_2 group of the first amino acid is blocked from getting involved into peptide bond formation with another amino acid. In the process the connection between tRNA and the amino acid at the P-site breaks. The free tRNA of the P-site slips to E-site and from there to the outside of ribosome with the help of G-factor. The A-site carries peptidyl tRNA complex.

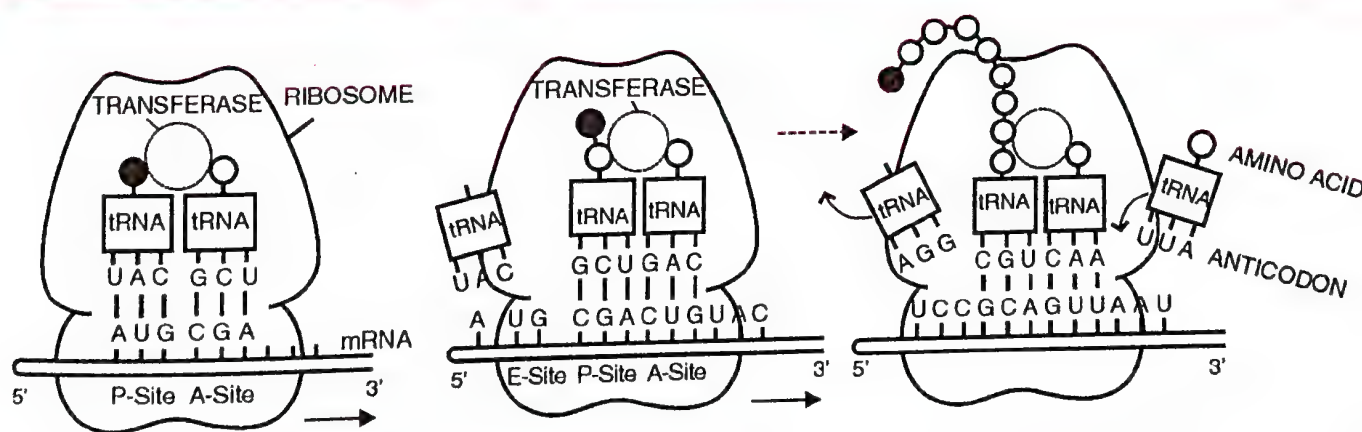


Fig. 6.36. Elongation of the polypeptide chain.

Soon after the establishment of first peptide linkage and slipping of the freed tRNA of P-site, the ribosome or mRNA rotates slightly. The process is called **translocation**. It requires a factor called **translocase** (EF-G in procaryotes and eEF2 in eucaryotes) and energy from GTP. As a result of translocation the A-site codon alongwith peptidyl-tRNA complex reaches the P-site. A new codon is exposed at the A-site. It attracts a new aminoacyl tRNA complex. The process of bond formation and translocation is repeated. One

by one all the codons of mRNA are exposed at the A-site and get decoded through incorporation of amino acids in the peptide chain. The peptide chain elongates. The elongated peptide chain or polypeptide lies in the groove of the larger subunit of ribosome to protect itself from cellular enzymes because it is prone to breakdown due to its extended nature. The helix formation begins at a distance with the help of **chaperones**.

A lot of energy is consumed in protein synthesis. For every single amino acid incorporated in peptide chain one ATP and two GTP molecules are used.

5. **Termination.** Polypeptide synthesis is terminated when a nonsense codon of mRNA reaches the A-site. There are three nonsense codons— UAA (ochre), UAG (amber) and UGA (opal). These codons are not recognised by any of the tRNAs. Therefore, no more aminoacyl tRNA reaches the A-site. The P-site tRNA is hydrolysed and the completed polypeptide is released in the presence of GTP-dependent **release factor**. It is single (eRF1) in eucaryotes and two (RF1 and RF2) in procaryotes. In procaryotes RF1 is specific for UAG and UAA. RF2 is specific for UAA and UGA. GTP dependent RF3 (eRF3 in yeast) is required for releasing the RFs from ribosome. Ribosome moves over the nonsense codon and slips off the mRNA chain. The two subunits of ribosome separate or undergo **dissociation** in the presence of dissociation factor (DF).

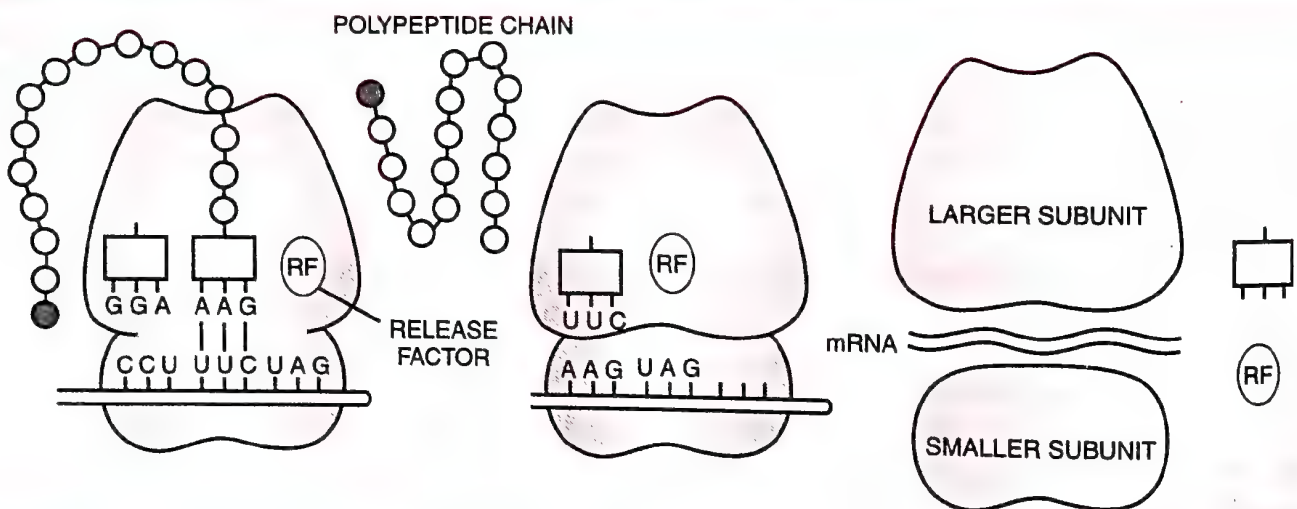


Fig. 6.37. Termination of polypeptide chain.

In procaryotes, formylated methionine is commonly the initiating amino acid. It is either deformed (with the help of enzyme deformylase) or some times removed from polypeptide (by enzyme aminopeptidase). The initiating methionine is usually not retained in eucaryotes. At a time several polypeptides are synthesised from the same mRNA by a polyribosome where a number of ribosomes are attached to the same mRNA strand. Each ribosome of a polyribosome forms the same type of polypeptide. Formation of a number of copies of the same polypeptide simultaneously from an mRNA with the help of a polysome is called **translational amplification**.

6. **Modification.** On being released from the ribosome, a polypeptide has only primary structure. It coils and folds further to have secondary and tertiary structure. A polypeptide may get associated with other polypeptides to produce β -pleated structure which then forms

tertiary and quaternary structure. In case of free cytoplasmic polyribosomes, the polypeptides or proteins are released in the cytoplasm (cytosol) where they are employed for synthesis of more cytoplasm, some enzymes and components of cell organelles like nucleus, microtubules, microfibrils, microbodies, etc. Some proteins also enter the composition of semi-autonomous organelles like plastids and mitochondria though they manufacture a part of their protein requirement themselves by their own polyribosomes. Polyribosomes attached to membranes of endoplasmic reticulum produce proteins which either pass into its lumen (Fig. 6.34 B) or become integrated into its membranes. The proteins released into E.R. lumen generally reach Golgi apparatus for modifications like formation of hydrolytic enzymes and glycosylation (addition of sugar residues). The modified proteins are packed in vesicles for export or formation of lysosomes, cell wall enzymes, plasma membrane, etc.

Protein synthesis is inhibited in bacteria by certain antibiotics. This forms the basis for treating certain bacteria infections.

Table 6.2. Antibiotic Inhibition of Bacterial Protein Synthesis

<i>Antibiotic</i>	<i>Effect</i>
Streptomycin	Inhibits initiation of translation and causes misreading.
Tetracycline	Inhibits binding of aminoacyl-tRNA to ribosome
Chloramphenicol	Inhibits peptidyl transferase and so formation of peptide bonds.
Erythromycin	Inhibits translocation of mRNA along ribosome
Neomycin	Inhibits interaction of tRNA with mRNA.
Puromycin	Binds to c-terminus of growing peptide chain and causes premature termination of protein polypeptide chain in both prokaryotes and eukaryotes.
Rifampicin and Actinomycin	Inhibit RNA synthesis by inhibiting RNA polymerase.

Differences Between Transcription and Translation

<i>Transcription</i>	<i>Translation</i>
<ol style="list-style-type: none"> 1. It is formation of RNA from DNA. 2. The template is antisense strand of DNA. 3. It occurs inside the nucleus in eukaryotes and cytoplasm in prokaryotes. 4. The raw materials are four types of ribonucleoside triphosphates — ATP, GTP, CTP and UTP. 5. It forms three types of RNAs — rRNA, tRNA and mRNA. 6. Transcription requires RNA polymerases and some transcription factors. 7. Polymerase moves over the template. 8. An adapter molecule is not required. 9. Product often requires splicing. 10. The product undergoes processing that involves cutting, modification of nitrogen bases, folding and attaching of specific groups at the ends. 	<ol style="list-style-type: none"> 1. It is synthesis of polypeptide over ribosome. 2. The template is mRNA. 3. It occurs in cytoplasm. 4. The raw materials are 20 types of amino acids. 5. All the three types of RNAs take part in translation. 6. Translation requires initiation, elongation and translocase factors. 7. Ribosome moves over mRNA. 8. Adapter (= adaptor) molecules bring amino acids over the template. 9. Splicing is absent. 10. Processing involves occasional modification of amino acids, combining with other substances (e.g., glycosylation) and packing.

Differences between Prokaryotic Translation and Eukaryotic Translation

Prokaryotic Translation	Eukaryotic Translation
<ol style="list-style-type: none"> 1. It occurs on 70 S ribosomes. 2. It is a continuous process as both transcription and translation occur in cytoplasm. 3. mRNA is polycistronic. 4. First amino acid taking part is f^{met}. 5. Initiation codon is usually AUG, occasionally GUG or UUG. 6. It is a faster process, adds about 20 amino acids per second. 7. It requires 3 initiation factors IF1, IF2, IF3. 8. After translation, formyl group from first formylated methionine is removed, retaining methionine in the polypeptide chain. 9. It requires two release factors RF1 (for UAG and UAA) and RF2 (for UAA and UGA) in the termination. 10. mRNA life is short (some seconds to some minutes) as mRNA is less stable. 	<ol style="list-style-type: none"> 1. It occurs on 80 S ribosomes. 2. It is a discontinuous process as transcription occurs in nucleus while translation takes place in cytoplasm. 3. mRNA is monocistronic. 4. First amino acid is met (methionine). 5. Initiation codon is AUG, occasionally GUG or CUG. 6. It is a slower process that adds one amino acid per second, thus a slower process. 7. It requires a set of 9 initiation factors eIF1, 2, 3, 4A, 4B, 4C, 4D, 5, 6. 8. The whole of initiating methionine is removed from the polypeptide chain. 9. It requires single release factor eRF1. 10. mRNA has a life of few hours to few days. It is quite stable.

REGULATION OF GENE EXPRESSION

Gene expression is the mechanism at the molecular level by which a gene is able to express itself in the phenotype of an organism. The mechanism of gene expression involves **biochemical genetics**. It consists of synthesis of specific RNAs, polypeptides, structural proteins, proteinaceous biochemicals or enzymes which control the structure or functioning of specific traits.

There are two types of genes, house keeping and regulated genes. **Housekeeping genes** are the ones which are continuously expressing themselves in all the cells of the body. It is because their product is always required, e.g., genes for glycolysis. Housekeeping genes are also called **constitutive genes**. Other genes which are not expressing their effect all the time in all the cells are called **non-constitutive** or **luxury genes**. Their activity is regulated and, therefore, they are called **regulated genes**. *Gene regulation is the mechanism of switching off and switching on of the genes depending upon the requirement of the cells and the state of development.*

Gene regulations are of two types, negative and positive. In **negative gene regulation**, the genes continue expressing their effect till their activity is suppressed. The **negative gene expression** is also called **repressible regulation**. The repression is due to a product of regulatory genes. **Positive gene regulation** is the one in which the genes remain non-expressed unless and until they are induced to do it. It is, therefore, **inducible regulation**. Here a product removes a biochemical that keeps the genes in non-expressed state. As the genes express their effect through enzymes, their enzymes are also called **inducible enzymes** and **repressible enzymes**.

In eukaryotes, the regulation of gene expression is exerted at four levels.

- (i) Transcriptional level – formation of primary transcript.
- (ii) Processing level – regulation of splicing.
- (iii) Transport of mRNA from nucleus to the cytoplasm.
- (iv) Translational level.

In prokaryotes, gene expression is regulated mostly at the site of transcriptional initiation. In a transcription unit, the activity of RNA polymerase at a given promoter is regulated by interaction with accessory proteins, which affects its ability to recognise start sites. These regulatory proteins can act both activators (positively) and repressors (negatively). The functioning of operator depends upon the protein products.

Gene expression is regulated by metabolic, physiological and environmental conditions.

Operon Concept

From a number of studies on the metabolism of bacterium *Escherichia coli*, two French scientists, **Jacob** (geneticist) and **Monod** (biochemist) in 1961 proposed a model of gene regulation, known as **operon model**. Operon is a co-ordinated group of genes such as structural gene, operator gene, promoter gene, regulator gene which function together and regulate a metabolic pathway as a unit, e.g., *lac* operon, *trp* operon, *ara* operon, *his* operon, *val* operon etc.

- (i) **Structural Gene.** Transcribes mRNA for polypeptide synthesis.
- (ii) **Operator Gene.** It is a gene which receives the product of regulator gene. It allows the functioning of the operon when it is not covered by the biochemical produced by regulator gene.
- (iii) **Promoter Gene.** Provides attachment site for RNA polymerase.
- (iv) **Regulator Gene.** It synthesises a biochemical or regulator protein which can act positively as activator and negatively as repressor. It controls, the activity of operator gene.

Repressor and **inducer** or co-repressor (from outside) are also found. Operator, promoter and regulator genes constitute the regulatory region. Operon systems are common in prokaryotes. The first operon *lac*-operon was discovered by Jacob and Monod (1961). Later on a number of such operons were discovered, e.g., *trp* -operon, *ara* -operon, *his* - operon, *val* -operon. Operons are of two types, **lac operon** or **inducible** and **tyrptophan operon** or **repressible**.

Lac Operon – Inducible Operon System (Fig. 6.38)

The *lac* refers to lactose. In *E. coli*, breakdown of lactose requires three enzymes. These enzymes are synthesised together in a co-ordinated manner by functional unit of DNA, i.e., *lac* operon. Since the addition of lactose itself stimulates the production of required enzymes, thus it is called **inducible operon system**. It consists of the following :

1. **Structural Genes.** Three structural genes are :

- (i) *lac z*. The *z* gene codes for β -galactosidase which is primarily responsible for the hydrolysis of the disaccharide, lactose into its monomeric units galactose and glucose.
- (ii) *lac y*. The *y* gene codes for permease, which increases permeability of the cell to β -galactosides.
- (iii) *lac a*. The *a* gene codes for transacetylase which can transfer acetyl group to β -galactoside.

2. **Operator gene.** It interacts with a protein molecule or regulator molecule, which prevents the transcription of structural genes.
3. **Promoter gene.** The gene possesses site for RNA polymerase attachment.
4. **Regulator gene (*i*).** The gene codes for a protein known as **repressor protein**, it is synthesised all the time from the *i*-gene, that's why it is constitutive gene which is functional always.

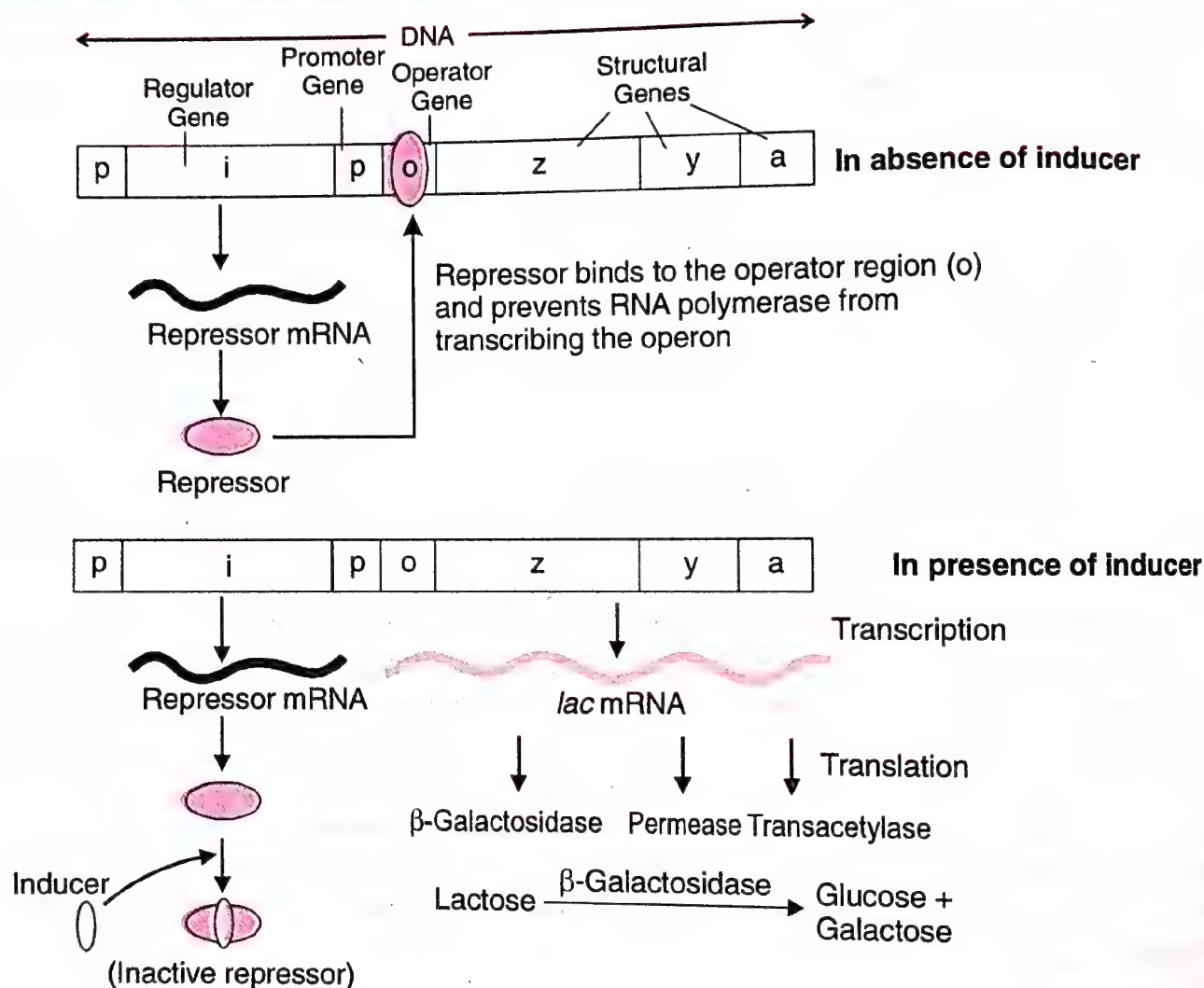


Fig. 6.38. The *lac* operon.

The operon is switched off when repressor protein produced by regulatory or inhibitor gene binds to operator gene. RNA polymerase gets blocked, so there would be no transcription.

Repressor protein + Operator gene \rightarrow Switched off

Regulation of *lac* operon by repressor is referred to as **negative control** or **regulation**.

If lactose is provided in the growth medium of the bacteria, the lactose is transported into the cells through the action of permease. A very low level of expression of *lac* operon has to be present in the cell all the time, otherwise lactose cannot enter the cells. In the presence of an inducer, such as lactose or allolactose, the repressor is inactivated by interaction with inducer. This allows RNA polymerase access to the promoter and transcription proceeds.

Inducer (Lactose) + Repressor \rightarrow Switched on
Lac operon is under control of positive regulation as well.

Tryptophan Operon – Repressible Operon System

Operon model can also be explained using feed-back repression. In tryptophan (*trp*) operon, three enzymes are necessary for the synthesis of amino acid tryptophan. These enzymes are synthesized by the activity of five different genes in a co-ordinated manner. The addition of tryptophan, however, stops the production of these enzymes. Thus, the system is known as **repressible system**.

It is commonly found in **anabolic pathways**. The operon is active and the enzymes produced by its structural genes are normally present in the cell. The functioning of the operon is stopped when the concentration of an end product crosses a threshold value. It was also worked out by Jacob and Monod and consists of the following :

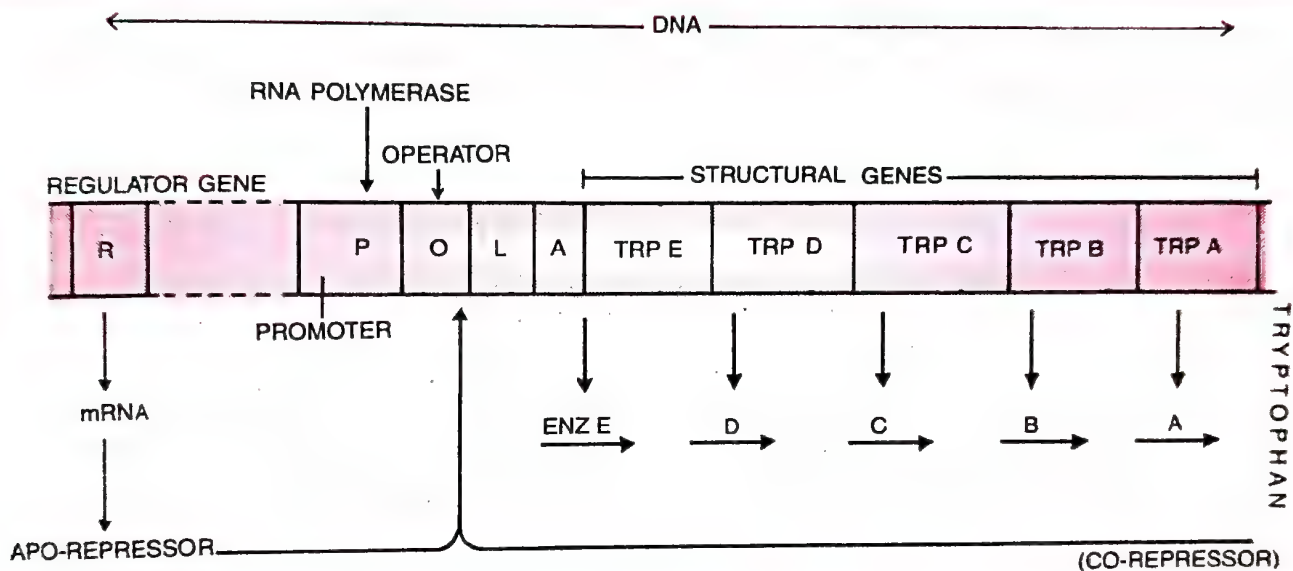


Fig. 6.39. Tryptophan Operon model of gene regulation in bacteria.

1. **Structural Genes.** The genes are connected to transcription of mRNAs. The mRNAs translate their coded information in the synthesis of polypeptides. Polypeptides give rise to proteinaceous substances including enzymes. Tryptophan operon has five structural genes—*trp* E, D, C, B, A. They form enzymes for five steps of tryptophan synthesis.

2. **Operator Gene.** It controls the functioning of structural genes. Normally it is kept switched on because the aporepressor produced by regulator gene is unable to completely block operator gene. The operator gene is switched off when a corepressor is available along with aporepressor.

3. **Promoter Gene.** It is the site for initial binding of RNA-polymerase. The latter travels from promoter gene to structural genes provided operator gene is switched on.

4. **Leader Attenuator (LA) Complex.** It lies between operator and structural genes. Attenuator slows down the activity of polymerase enzyme when tryptophan concentration begins to rise. This happens without blocking the operon.

5. **Regulator Gene (*trp* R).** It forms a proteinaceous component for possible blocking the activity of operator gene. Regulator gene of tryptophan operon lies at a distance away from the remaining operon.

Aporepressor. It is a proteinaceous substance synthesised by regulator gene. Aporepressor forms a component of repressor for blocking the working of operator gene. For this it requires a corepressor. When the latter is not available in proper strength, the operator gene is kept switched on because by itself, aporepressor is unable to block the working of operator gene.

Corepressor. It is a nonproteinaceous component of repressor which is also an end product of reactions catalysed by enzymes produced through the activity of structural genes. The end product is often utilized in some other reaction so that it rarely accumulates and hence does not function as corepressor. However, whenever it accumulates or becomes available from outside source, the end product becomes corepressor, combines with aporepressor, forms repressor and blocks the operator gene. The structural genes now stop transcription. The phenomenon is known as **feed-back repression**. It exerts a **negative control**. In tryptophan operon, tryptophan (an amino acid) functions as corepressor.

Differences between Inducible and Repressible Operon

<i>Inducible Operon</i>	<i>Repressible Operon</i>
<ol style="list-style-type: none"> 1. It is an operon which normally remains switched off. 2. It is switched on by the presence of a biochemical called inducer. 3. Induction of the operon involves removal of repressor from the operator gene. 4. The regulator gene of the operon produces a complete repressor. 5. Induction starts transcription and translation. 6. Inducible operon is functional in catabolic pathway. 7. Induction is caused by a new metabolite. 	<ol style="list-style-type: none"> 1. The operon normally remains switched on. 2. An inducer has no role in repressible operon. 3. Repression involves binding of repressor over the operator gene. 4. The regulator gene forms only a part of repressor called aporepressor. 5. Repression stops transcription and translation. 6. It is connected with anabolic pathway. 7. Repression is caused by excess availability of an existing metabolite.

Regulation of Gene Expression in Eukaryotes

Britten-Davidson gene battery model is most popular for eukaryotic genes expression. It proposes the occurrence of 5 types of genes — producer, receptor, integrator, sensor and enhancer silencer.

1. **Producer or Structural Genes.** These genes transcribe *mRNAs*. They occur singly. For example, human haemoglobin is formed of two types of polypeptides, α and β . Their producer genes are situated on chromosomes 16 and 11 respectively.

2. **Receptor or Operator Gene.** Every producer gene seems to have its own receptor or operator gene that lies nearby. The receptor gene after receiving information from integrator gene provides site for RNA polymerase.

3. **Integrator or Regulator Gene.** It controls the functioning of operator gene by forming an activator RNA. The RNA regulates the functioning of receptor gene.

4. **Sensor Gene.** The gene is meant for picking up information of the intracellular environment. The information is contained in various metabolites, vitamins, hormones, ions, pathogens, etc. Any of them can function as a transcription factor.

5. **Enhancer-Silencer Genes.** They change the rate of transcription of structural genes.

Advantages of Gene Regulation

1. A number of related genes required for a particular metabolic activity can be switched on or off simultaneously.
2. Gene regulation enables the cell to adjust metabolism as per requirement of environmental changes and development.
3. It is economical as it synthesises enzymes only when required.
4. Gene regulation helps in growth and differentiation.
5. It is helpful in smooth completion of chain reactions.

HUMAN GENOME PROJECT (HGP)

Each individual has an identity that is due to one's genetic make up. No two individuals are similar (except monozygote twins) because they differ in their genetic make-up. Differences in genetic make-up are due to differences in nucleotide sequences of their DNAs. It was, therefore, always an ambition of scientists to map human genome. Advances in genetic engineering techniques made it possible to isolate and clone DNA pieces and determine nucleotide sequences of these fragments. Therefore, in 1990, U.S. Department of Energy and National Institute of Health embarked and coordinated on the project of sequencing human genome called **HGP** or **Human Genome Project**. Wellcome Trust (UK) joined the project as a major partner. Later on Japan, France, Germany, China and some other countries also joined it.

John Craig Venter. One of the first scientists to sequence Human Genome.

The Human Genome Project was launched on October 1, 1990. The project was completed in 2003. Thus it was a 13 year project.

HGP has been called a megaproject due to

- (i) Huge cost estimated to be 9 billion US dollars.
- (ii) Very large number of base pairs (3×10^9 bp) to be identified and sequenced.
- (iii) A large number of scientists, technicians and supporting staff.
- (iv) Storage of data generated which requires some 3300 books, each with 1000 pages and each page having 1000 typed letters. However, high-speed computational devices for storage, retrieval and analysis of data made it easier to do the same.
- (v) The science of **Bioinformatics** also developed during this period and helped HGP.

Bioinformatics is a new field in which computer hardware and software technologies are developed and used to gather, store, analyze and disseminate biological data, images and other information.

Goals of HGP

HGP had set the following goals.

- (i) Identification of all the approximately 20,000-25,000 genes in human DNA.
- (ii) To determine the sequences of the 3 billion chemical base pairs that make up human DNA.
- (iii) To store this information in databases.
- (iv) To improve tools for data analysis.
- (v) Transfer-related technologies to other sectors, such as industries.

(vi) **ELSI.** To solve any ethical, legal and social issues (ELSI) that may arise from the project.

(vii) **Bioinformatics,** i.e., close association of HGP with the rapid development of a new area in biology.

(viii) **Sequencing of model organisms.** Non-human organisms DNA sequences can lead to an understanding of their natural capabilities that can be applied towards solving challenges in health-care, agriculture, energy production, environmental remediation. Many non-human model organisms such as bacteria, yeast, *Caenorhabditis elegans* (a free-living non-pathogenic nematode), *Drosophila*, plants like rice and *Arabidopsis*, etc., have been sequenced. As for examples :

Organisms	Base pairs	No. of genes
<i>E. coli</i>	4.7 million	4,000
<i>Saccharomyces cerevisiae</i>	12 million	6,000
<i>Caenorhabditis elegans</i>	97 million	18,000
<i>Drosophila melanogaster</i>	180 million	13,000
<i>Arabidopsis</i>	130 million	25,000
<i>Oryza sativa</i>	430 million	32000–50000

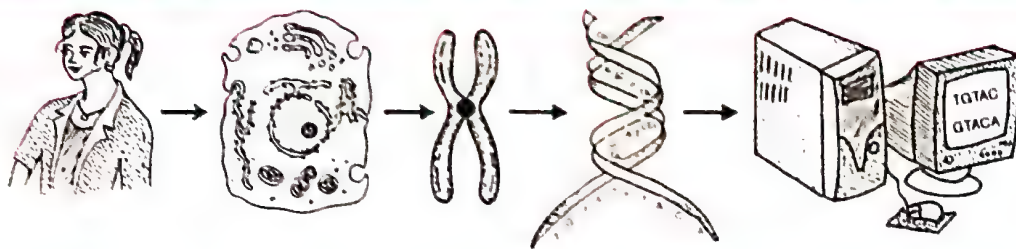


Fig. 6.40. Human Genome Project.

Methodologies

There are two approaches for sequencing human genome. (i) **Expressed Sequence Tags (ESTs).** Identify all the genes that are expressed as RNAs and sequence the same. (ii) **Sequence Annotation.** The whole genome, including both coding and non-coding regions is first sequenced. Later, functions are assigned to different regions. In HGP, sequence annotation has been carried out which involves following steps.

- (i) The whole DNA of the cell is isolated and broken randomly into fragments.
- (ii) They are inserted into specialised vectors like **BAC** (bacterial artificial chromosomes) and **YAC** (yeast artificial chromosome).
- (iii) The fragments are cloned in suitable hosts like bacteria and yeast. **PCR** (polymerase chain reaction) can also be used for cloning or making copies of DNA fragments.
- (iv) The fragments are sequenced as **annotated DNA sequences** (an offshoot of methodology developed by double Nobel laureate, Friedrich Sanger).
- (v) The sequences were then arranged on the basis of some overlapping regions. It necessitated the generation of overlapping fragments for sequencing.

- (vi) Computer based programmes were used to align the sequences.
- (vii) The sequences were then annotated and assigned to different chromosomes. All the human chromosomes have been sequenced, 22 autosomes, X and Y. Chromosome 1 was last to be sequenced in May, 2006.
- (viii) With the help of polymorphism in microsatellites and restriction endonuclease recognition sites, the genetic and physical maps of the genome have also been prepared.

Salient Features of Human Genome

1. Human genome contains 3164.7 million nucleotide bases (base pairs).
2. The average gene consists of 3000 bases, but sizes vary greatly. The total number of genes is about 30,000. Previously it was believed that human beings carry 80,000–140,000 genes.
3. The size of genome or number of genes is unconnected with the complexity of body organisation. Lily has 18 times more DNA than human genome. In spite of this fact, Lily produces fewer proteins than a human being.
4. The function of over 50% of the discovered genes is unknown.
5. Less than 2% of the genome contains coded information for protein synthesis.
6. By differential splicing, a gene may code for two or more proteins.
7. Chromosome I has maximum number of genes (2968) while Y-chromosome has minimum number of genes (231). They are the maximum and minimum genes for the human chromosomes.
8. 99.9% of the nucleotide bases are exactly similar in all human beings.
9. The length of different human genes varies widely. The average gene size is 3000 bp. β -globin or insulin genes are less than 10 kilo base pairs long. The largest gene of human body is that of **Duchenne Muscular Dystrophy** on 'X' chromosome. It is 2.4 million (2400 kilo) base pairs long. The smallest gene is that of TDF (Testis Determining Factor), a holandric gene, present on 'Y' chromosome. It is only 14 base pairs long (Page *et al*, 1987).
10. Part of DNA which contains repeated sequences is called **satellite DNA**. Satellite DNA is of several types. One of them is **moderately repetitive sequences** of 150–300 base pairs long. They include transposons and Alu elements. There are several thousand Alu repeats in human genome. **Mini-satellite sequences** are 11–60 base pairs long hypervariable repeat sequences. They are VNTRs used in DNA fingerprinting. Over a million copies of **simple sequence repeats (SSR)** or **microsatellites** occur in the genome. They have 5–8 pairs. These sequences are clustered around centromeres and near the ends of chromosomes. These repeated sequences are called **junked DNA**. Repetitive sequences have no direct coding functions. They, however, provide information about chromosome structure, dynamics and evolution.
11. About 1.4 million single base DNA differences or **single nucleotide polymorphisms (SNPs)**, pronounced as 'snips' have been identified in humans. Their number may be more than 10 million (Lewin, 2008). This will be helpful in finding chromosomal locations with disease associated sequences and tracing human history.

Applications and Future Challenges

1. **Disorders.** More than 1200 genes are responsible for common human cardiovascular diseases, endocrine diseases (like diabetes), neurological disorders (like Alzheimer's disease), cancers and many more.

2. **Cancers.** Efforts are in progress to determine genes that will change cancerous cells to normal.

3. **Health Care.** It will indicate prospects for a healthier living, designer drugs, genetically modified diets and finally our genetic identity.

4. **Interactions.** It will be possible to study how various genes and proteins work together in an interconnected network.

5. **Study of Tissues.** All the genes or transcripts in a particular tissue, organ or tumor can be analysed to know the cause of effect produced in it.

6. **Nonhuman Organisms.** Information about natural capabilities of nonhuman organisms can be used in meeting challenges in health care, agriculture, energy production and environmental remediation. For this a number of model organisms have been sequenced, e.g., bacteria, yeast *Coenorhabditis elegans* (free living nonpathogenic nematode), *Drosophila* (fruitfly), Rice, *Arabidopsis* etc.

RICE GENOME PROJECT

An International Rice Genome Sequencing Project (IRGSP) was conceived in September 1997. Some 32 institutions of ten countries participated in it. The Indian participants were IARI and University of Delhi. The tools used in sequencing were BAC (bacterial artificial chromosomes) and PAC (P1-phage derived artificial chromosomes). The map based draft sequence was released in December, 2002.

1. Rice has the smallest genome amongst the major cereals with only 389 million base pairs.
2. The number of genes is, however, high, some 37544. Many of them occur in clustered gene families.
3. Nearly 0.4% of nuclear genes contain organelle DNA segments.
4. Number of transposons is quite high, some 35%.
5. 18.9 million SNPs and 80,127 polymorphic sites occur in the genome.
6. There are five varietal groups in Rice : (i) Basmati (ii) Indica (iii) Aus (iv) Tropical japonica and (v) Temperate japonica.

DNA FINGERPRINTING

Historical Aspect

The study of finger, palm and sole prints is called **dermatoglyphics**. It has been a subject of human interest since primitive times when man used to hunt for his food with the help of animal's foot prints. Science of fingerprinting was first used by Sir William Herschel as a method of identification in 1858. In India the science of fingerprints was discovered by chance during a murder investigation in Jalpaiguri in 1897.

Alec Jeffreys (1984) invented the DNA fingerprinting technique at Leicester University, United Kingdom. **Dr. V.K. Kashyap** and **Dr. Lalji Singh** started the DNA fingerprinting technology in India at CCMB (Centre for Cell and Molecular Biology) Hyderabad.

Alec Jeffreys — Father of DNA Fingerprinting
Lal ji Singh — Father of Indian Fingerprinting



Sir Alec Jeffreys.

What is DNA-fingerprinting ?

DNA-fingerprinting (also called *DNA typing* or *DNA profiling*). It is a technique of determining nucleotide sequences of certain areas of DNA which are unique to each individual. Each person has a unique DNA fingerprint. Unlike a conventional fingerprint that occurs only on the fingertips and can be altered by surgery, a DNA fingerprint is the same for every cell, tissue and organ of a person. It cannot be changed by any known treatment. The ideal way to distinguish an individual from other people would be his or her entire genomic DNA sequence.

Principle of DNA Fingerprinting

By their differences, about 0.1% or 3×10^6 base pairs (out of 3×10^9 bp) provide individuality to each human being. Human genome possesses numerous small noncoding but inheritable sequences of bases which are repeated many times. These sequences occur near telomere, centromeres, Y chromosome and heterochromatic area. The area with same sequence of bases repeated several times is called repetitive DNA. They can be separated as **satellite** from the bulk DNA during density gradient centrifugation and hence called satellite DNA. In satellite DNA, repetition of bases is in tandem. Depending upon length, base composition and numbers of tandemly repetitive units, satellite DNAs have subcategories like **microsatellites** and **minisatellites**. Satellite DNAs show polymorphism. The term polymorphism is used when a variant at a locus is present with a frequency of more than 0.01 population. Variations occur due to mutations. While mutations in genes produce alleles with different expressions, mutations in noncoding repetitive DNA have no immediate impact. These mutations in the noncoding sequences have piled up with time and form the basis of DNA **polymorphism** (variation at genetic level arises due to mutations). DNA polymorphism is the basis of genetic mapping of human genome as well as DNA finger printing.

Short nucleotide repeats in the DNA are very specific in each individual and vary in number from person to person but are inherited. These are the '**Variable Number Tandem Repeats**' (VNTRs). These are also called "**minisatellites**". Each individual inherits these repeats from his/her parents which are used as genetic markers in a personal identity test. For example (Fig. 6.41), a child might inherit a chromosome with six tandem repeats from the mother and the same tandem repeated four times in the homologous chromosome inherited from the father. One half of VNTR alleles of the child resemble that of the mother and other half with that of the father.

Technique For DNA Fingerprinting (Fig. 6.42)

1. The DNA is extracted from the nuclei of white blood cells or of spermatozoa or of the hair follicle cells that cling to the roots of hairs that have fallen, or been pulled out.
2. The DNA molecules are first broken with the help of enzyme restriction endonuclease

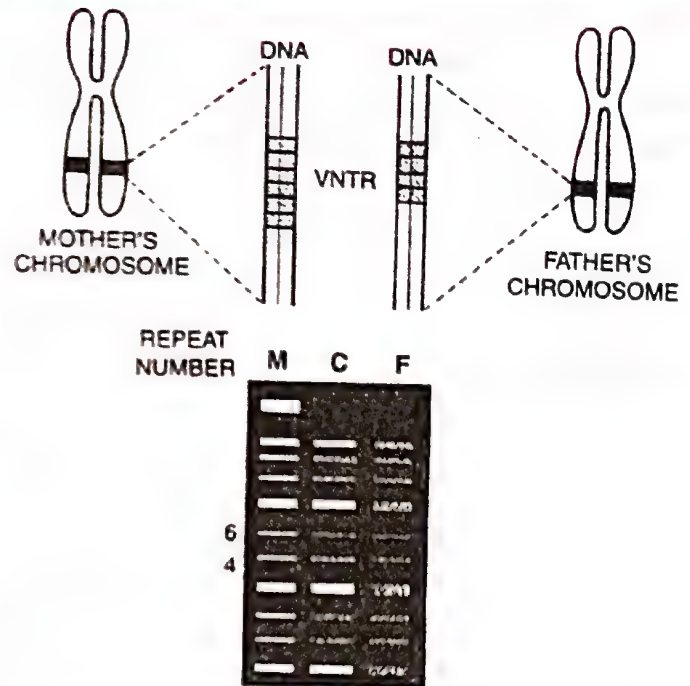


Fig. 6.41. Variable Number Tandem Repeats (M = mother, F = father; C = child)

(called chemical knife) that cuts them into fragments. The fragments of DNA also contain the VNTRs.

3. The fragments are separated according to size by gel electrophoresis.

4. Fragments of a particular size having VNTRs are multiplied through PCR technique. They are treated with alkaline chemicals to split them into single stranded DNAs.

5. The separated fragments of single stranded DNA are transferred onto a nylon membrane.

6. **Radioactive DNA probes** having repeated base sequences complementary to possible VNTRs are poured over the nylon membrane. Some of them will bind to the single stranded VNTRs. The method of hybridization of DNA with probes is called **Southern Blotting**, after the name of the inventor, E.M. Southern (1975). The nylon membrane is washed to remove extra probes.

7. An X-ray film is exposed to the nylon membrane to mark the places where the radioactive DNA probes have bound to the DNA fragments. These places are marked as dark bands when X-ray film is developed. This is known as **autoradiography**.

8. The dark bands on X-ray film represent the **DNA fingerprints (= DNA profiles)**.

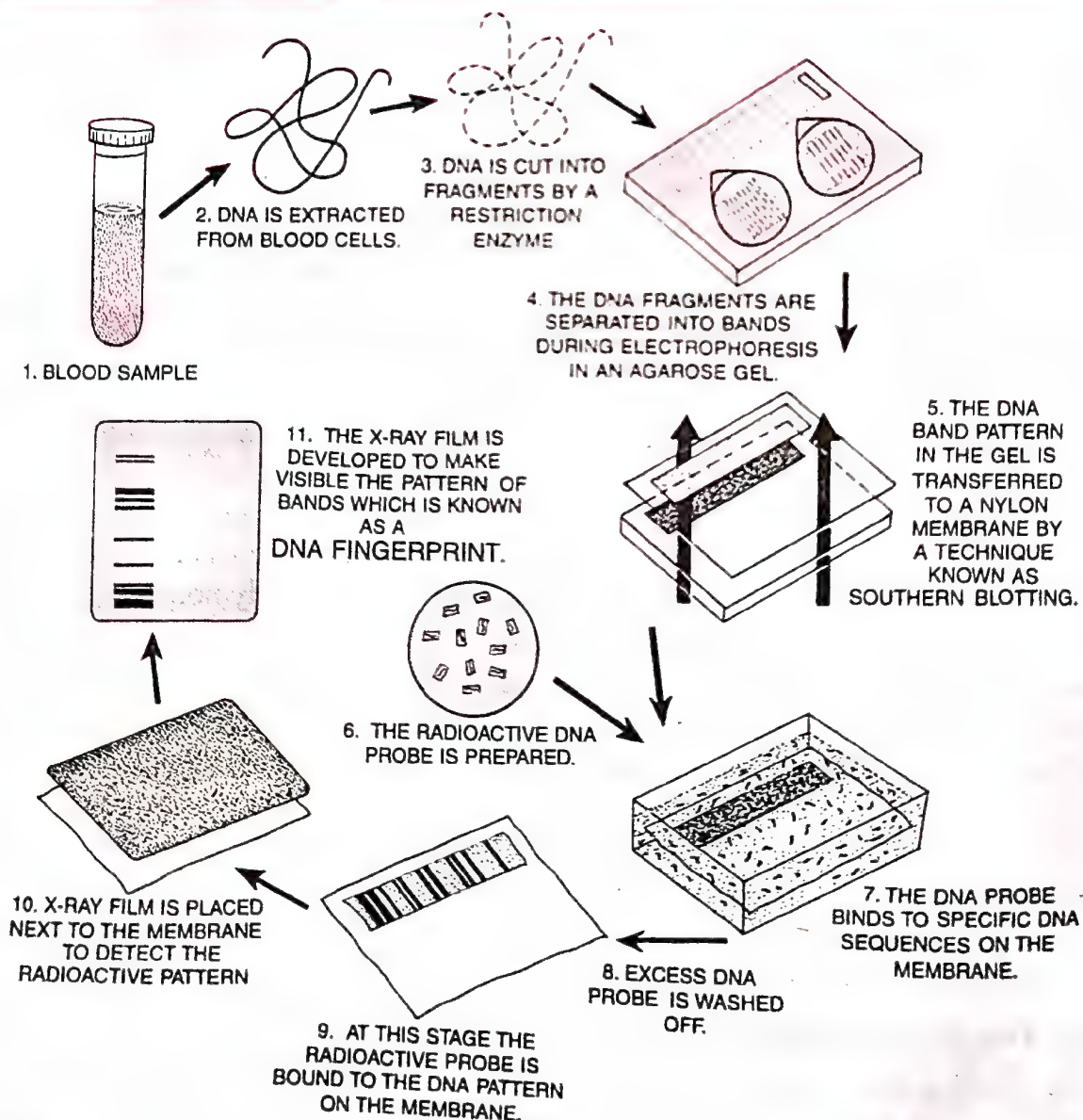


Fig. 6.42. The DNA Fingerprinting Process.

Differences between VNTR and Probe

VNTR	Probe
<ol style="list-style-type: none"> 1. It is a natural small sequence of DNA. 2. VNTR is non-radioactive. 3. VNTRs help in identification of a person. 	<ol style="list-style-type: none"> 1. It is synthetic DNA fragment. 2. It is radioactive. 3. Probes help in identification of VNTRs.

Applications of DNA Fingerprinting

1. **Individuality.** Like skin finger printing (dermatoglyphics), DNA finger printing can help to distinguish one human being from another with exception of monozygotic twins.

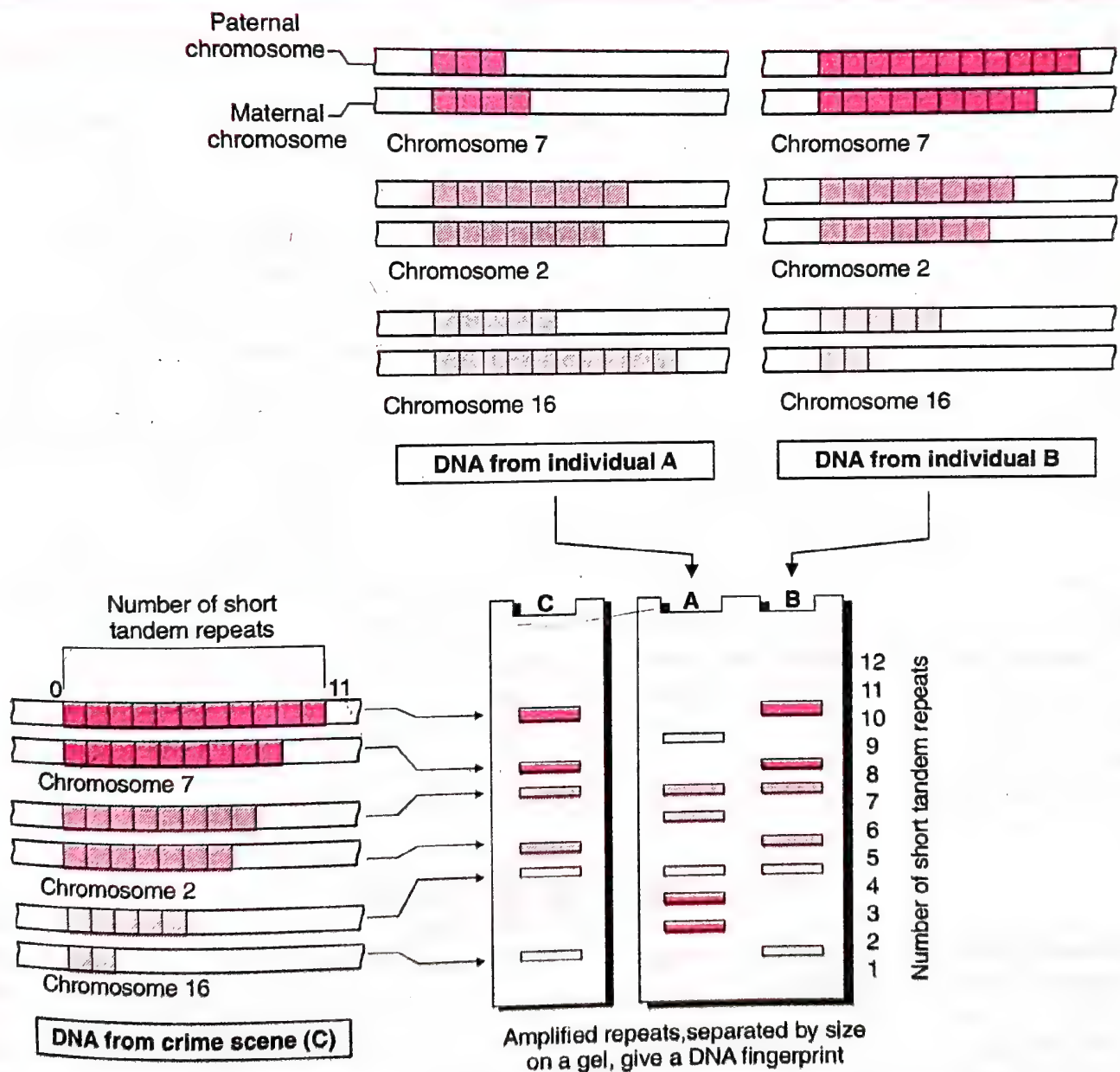


Fig. 6.43. Schematic representation of DNA fingerprinting : Few representative chromosomes have been shown to contain different copy number of VNTR. For the sake of understanding different colour schemes have been used to trace the origin of each band in the gel. The two alleles (paternal and maternal) of a chromosome also contain different copy numbers of VNTR. It is clear that the banding pattern of DNA from crime scene matches with individual B and not with A.

2. **Paternity/Maternity Disputes.** DNA finger printing can identify the real genetic mother, father and the offspring.

3. **Human Lineage.** DNA from various probables is being studied to find out human lineage.

4. **Hereditary Diseases.** The technique is being used to identify genes connected with hereditary diseases.

5. **Forensics.** DNA finger printing is very useful in the detection of crime and legal pursuits. DNA fingerprinting has proved that Dhanu, the human bomb, was the real murderer of Shri Rajiv Gandhi, the former Prime Minister of India.

6. **Sociology.** It can identify racial groups, their origin, historical migration and invasions. **Genography** is the study of migratory history of human species.

GENOMICS

Meaning of Genomics. The word "genomics" has taken root from the term "genome" which is an organisms's total genetic constitution. The term "genomics" was introduced in 1986 by Thomas Roderick to describe the *scientific discipline of mapping, sequencing, and analysing genomes*. Infact genomics is the study of genes, their structure and functioning.

Our body contains 100 trillion cells of over 260 different kinds. In all, there are 23 different chromosomes containing packed DNA in a haploid set of human genome. Additional DNA is in cell's mitochondria which is inherited from one's mother.

Components of Genomics. Genomics has two components, structural genomics and functional genomics.

(a) **Structural genomics** is genome analysis and construction of high resolution genetic, physical and transcript maps of an organism. The physical map of an organism developed through genome analysis is its complete DNA sequence.

(b) **Functional genomics** is the development and application of experimental approaches to assess gene function by making use of the information and tools provided by structural genomics. It gives detailed understanding of gene functions.

Application of Genomics. (i) Genomics is engaged in identifying various human genes. (ii) It gives information about functions of different genes. (iii) It enhances basic understanding of human genetics. (iv) It gives information that will help to prevent inherited diseases. (v) It can lead to treatment of genetic disorders through gene therapy. (vi) Genomics has important role in animal breeding. (vii) It is useful in production of transgenic organisms

ADDITIONAL INFORMATION

- **rDNA.** DNA present in nucleolar organiser region which is specialized to transcribe rRNAs. It has a number of repeat units.
- **P DNA** is an alternative form of DNA. It is longer, narrower with 2.62 bp per turn with bases outward and phosphate groups inside.
- **Selfish DNA.** It is that region of DNA which has no function. It exists only to pass copies of itself into next generation.
- **Highly Repetitive DNA.** It consists of short simple sequences which are repeated hundreds of thousands times (Skinner, 1978). Satellite DNA is highly repetitive DNA, e.g., pericentromeric regions of chromosomes. Heterochromatic region of Y-chromosome has special satellite DNA found only in male cells.
- **Moderately Repetitive DNA.** They are repeated a few hundred times. Centromere,

- telomere, and ends of transposons have moderately repetitive DNA.
- **Minisatellite Sequences**(Jeffreys, 1985). They are hypervariable repeat sequences of DNA, 11-60 base pairs and flanked by conserved restriction sites.
- **Microsatellite Sequences.** They are simple sequence repeats with 1-6 base pairs and flanked by conserved sequences.
- **Mini-Microsatellite DNA.** Portions of DNA that have small repeats unique to each person. Used for DNA finger printing.
- **DNA Redundancy.** Functional DNA is less than 1%. The remaining is repetitive DNA, pseudogenes, repeated genes and introns.
- **Artificial Gene.** First artificial gene was synthesised by Khorana *et al* (1968). It was alanine-tRNA gene with 77 base pairs. The gene, however, did not function in living system. Their second artificial and functional gene was tyrosine-tRNA gene with 207 base pairs (Khorana *et al*, 1979).
- **Signal Theory.** Secretory proteins often possess a small extra peptide known as **signal peptide**. It is recognised by scRNA-protein complex (SRP). The complex helps in moving the ribosome to reach endoplasmic reticulum where the complex separates along with the extra peptide.
- **Seymour Benzer** (1962). Distinguished **cistron**, **recon** and **muton** as three structural units of DNA. Other workers added the terms of **replicon** (unit of replication), **complon** (unit of complementation), **operon** (operational unit) and **codon** (a sequence of three nucleotides specifying an amino acid).
- **Bishop and Varmus.** Discovered oncogenes.
- **Barbara Mc Clintock.** Discovered jumping genes in 1951. Nobel Prize in 1983. The term **transposon** was given by Hedges and Jacob (1974).
- **RNA Silencing.** Discovery by Fire *et al* (1998) in *C. elegans* that short double stranded RNAs can not only trigger mRNA degradation but also cause silencing of genes. The phenomenon is called RNA interference. Double stranded RNAs produce short interfering RNAs (si RNAs) for silencing genes.
- **mi RNAs.** Micro RNAs are small sized RNAs (21-25 nucleotides length) formed from nonprotein encoding genes which are used as gene regulators in many eukaryotes.
- Hybrid DNA formed as a result of recombination is called **heteroduplex DNA** (also called heterozygous DNA).
- **Neoplasm.** New growth, tumour, abnormal tissue formed by cell proliferation more rapid than normal, may be benign or malignant.
- **Herman Muller** (1965) proposed of setting sperm-egg banks since sex cells can be kept alive and functional for considerable periods by freezing.
- **Consanguineous Marriages.** Marriages between related individuals.
- **Heterosis** (hybrid vigour)— The superiority of hybrid.
- In India plant breeding is actively carried out at Indian Agricultural Research Institute, Delhi; Central Potato Research Institute, Shimla, Rice Research Institute, Cuttack and Sugarcane Research Institute, Coimbatore and at a number of Agricultural Universities and Research Stations.
- **Kalyan Sona**, a wheat variety has been developed from the imported Mexican variety. **Sharbati Sonora** has been produced from Sonora-64 by inducing mutation with gamma radiation. Sharbati wheat of Madhya Pradesh is rust resistant. Wheat varieties C-250, C-228 are resistant to yellow rust.
- **Z-DNA** was discovered by **Andrew Wang** and **Alexander Rich** in 1979.
- **Ribozymes** are RNA molecules with catalytic activity, *i.e.*, RNA acting as enzyme.
- Human Y-Chromosome was discovered by **Painter** in 1923.
- The correct human chromosome number $2N = 46$ was discovered by **Tjio** and **Levan** in 1956.
- Patients of CML (**Chronic Myeloid Leukemia**) carry "**Philadelphia Chromosome**" which is one of 22 chromosomes that has lost most of the distal part of its longer arm. Philadelphia chromosome was first reported from a patient in Philadelphia, USA in 1959.
- **Garrod**— "**Father of Physiological Genetics**" or "**Father of Biochemical Genetics**".
- **Galton**— "**Father of Eugenics**". Eugenics is a branch of science which deals with improvement of human race genetically.
- **Simian Cloning** (cloning of monkeys) was carried out by **Don Wolf** (USA) in 1996 from an eight cell embryo.

- The first cloned calves **George and Charlie** were born in January 1998.
- Dolly was a clone of a sheep, made by using 3 sheep.
- **ANDI** (a monkey) was first transgenic primate in which DNA of Jelly fish was inserted.
- **Genome.** The term was coined by H. Winkler (1920).

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

- Group the following as nitrogenous bases and nucleosides : Adenine, Cytidine, Thymine, Guanosine, Uracil and cytidine.
✓ **Nitrogen bases** : Adenine, thymine, uracil ; **Nucleosides** : Cytidine, Guanosine.
- If double stranded DNA has 20% of cytosine, calculate the percent of adenine in the DNA.
✓ Cytosine = 20%, Guanine = 20% (Chargaff's rule).
 $A + T = 100 - 40 = 60\%$. Both are in equal amounts.
$$\therefore \text{Adenine} = \frac{60\%}{2} = 30\%$$
- If the sequence of one strand of DNA is written as follows
5' – ATGCATGCATGCATGCATGCATGC –3'
Write down the sequence of complementary strand in 5' → 3' direction.
✓ 5'-ATGCATGCATGCATGCATGCATGC- 3'
Normal direction of 3'-TACGTACGTACGTACGTACGTACG-5' complementary strand
5' → 3' direction of complementary strand 5'-GCATGCATGCATGCATGCATGCATGC-3'
- If the sequence of coding strand in a transcription unit is written as follows : 5' – ATGCATGCATGCATGCATGCATGCATGC –3', write down the sequence of m-RNA.
✓ mRNA carries the same code as coding strand with the exception of T being replaced by U.
 \therefore 5' -AUG CAU GCA UGC AUG CAU GCA UGC AUGC- 3'
- Which property of DNA double helix led Watson and Crick to hypothesize semiconservative mode of DNA replication. Explain.
✓ The two strands of DNA have complementary base pairs which run in opposite directions. The two properties of DNA led Watson and Crick to suggest semiconservative mechanism of DNA replication in which one strand of parent is conserved while the other complementary is formed anew.
- Depending upon the chemical nature of template (DNA or RNA) and the nature of nucleic acids synthesised from it (DNA or RNA), list the types of nucleic acid polymerases.
✓ **DNA Template.** (i) DNA polymerases for DNA replication. (ii) RNA polymerases for RNA synthesis or transcription.
RNA Template. (i) RNA dependent RNA polymerases for synthesis of gRNA in some RNA viruses. (ii) Reverse transcriptase to synthesize cDNA over RNA template.
- How did Hershey and Chase differentiate between DNA and protein in their experiment while proving that DNA is the genetic material ?
✓ Hershey and Chase (1952) grew cultures of *E.coli* in medium rich in radioactive sulphur (S^{35}) and Phosphorous (P^{32}). S^{35} gets incorporated into sulphur containing amino acids of protein while P^{32} into nucleic acid (DNA). They then introduced separately T_2 bacteriophage in both the above labelled cultures of *E.coli* for their (viral phage) multiplication. The S^{35} was incorporated into the protein coat of virus in that culture of *E. coli* which was labelled with S^{35} . P^{32} was found in case of nucleic acid (DNA) of that virus which was labelled with S^{35} . P^{32} was labelled with P^{32} . Actually Sulphur is a component of few sulphur containing amino acids (methionine and cysteine) in protein. Phosphorus is a component of nucleotides in DNA/RNA. On this basis, Hershey and Chase differentiated between DNA and protein while providing that DNA is the genetic material.
- Differentiate between the following :
(a) Repetitive DNA and satellite DNA
(b) mRNA and tRNA
(c) Template strand and coding strand.
✓ (a) Differences between Repetitive DNA and Satellite DNA :

Differences between Repetitive DNA and Satellite DNA

Repetitive DNA	Satellite DNA
<ol style="list-style-type: none"> 1. It is sequence of nitrogen bases present in more than one copy in a genome. 2. Length of repetitive DNA varies from a few nitrogen bases to several hundred. 3. Repeated DNA sequences may or may not be present in tandem. 4. It does not separate during density gradient ultracentrifugation. 5. Variability may or may not be present. 	<ol style="list-style-type: none"> 1. It is part of DNA having highly repeated short sequences of nitrogen bases. 2. Length of DNA sequence of satellite DNA is short, 1-60 bp. 3. Repeated sequences of nitrogen bases occur in tandem. 4. It separates out during density gradient ultracentrifugation. 5. Variability occurs during misalignment in chromosome pairing.

(b) Differences between mRNA and rRNA

✓ Refer to text

(c) Differences between Template Strand and Coding Strand

Differences between Template Strand and Coding Strand

Template Strand	Coding Strand
<ol style="list-style-type: none"> 1. It is strand of DNA which takes part in transcription. 2. The polarity is 3' → 5'. 3. Nucleotide sequence is complementary to one present in mRNA. 	<ol style="list-style-type: none"> 1. It does not take part in transcription. 2. The polarity is 5' → 3'. 3. The nucleotide sequence is the same to the one present in mRNA except for presence of T instead of U.

9. List two essential roles of ribosome during translation.

✓ Two essential roles of ribosomes during translation are (i) They provide surface for binding of mRNA in the groove of smaller subunit of ribosome. (ii) As larger subunit of ribosome has peptidyl transferase on its 'P' site, therefore, it helps in joining aminoacids by forming peptide bonds.

10. In the medium where *E. coli* was growing, lactose was added, which induced the *lac*-operon. But why does *lac*-operon shut down after some time after addition of lactose in the medium?

✓ *Lac* operon is switched on adding lactose in the medium, as lactose acts as inducer and make repressor inactive. Due to this switch on of *lac* operon system, β -galactosidase is formed which converts lactose into glucose and galactose. As soon as lactose is consumed, repressor again become active and cause switch off (shut down) of system.

11. Explain (in one or two lines) the functions of the following (a) Promoter (b) tRNA (c) Exons.

✓ **Promoter** : It is one of the three components of a transcription unit that takes part in transcription. It is located at the start 5' end and provides site for attachment of transcription factors (TATA Box) and RNA polymerase.

tRNA : It takes part in the transfer of activated amino acids from cellular pool to ribosome for their taking part in protein formation.

Exons : In eukaryotes, DNA is mosaic of exons and introns. Exons are coding sequences of DNA which are transcribed and translated both.

12. Why is human genome project called a mega project ?

✓ Refer to text.

13. What is DNA finger printing ? Mention its applications.

✓ **Definition.** DNA finger printing or DNA profiling (Jeffreys *et al*, 1985) is the technique of determining similarity or dissimilarity of VNTRs between two samples of DNA so as to bring out relationship if any. VNTRs are specific for each individual. They are derived from the two parents in 50 : 50 ratio.

Application. Refer to text.

14. Briefly describe the following : Transcription, Polymorphism, Translation, and Bioinformatics.

✓ **Transcription.** It is DNA directed synthesis of RNA in which the RNA is transcribed on 3 → 5' template strand of DNA in 5 → 3 direction. It occurs in G_1 , S and G_2 , i.e., throughout interphase stage of cell cycle.

Polymorphism (Genetic Polymorphism). In this form of polymorphism there is variation in DNA at a given genomic site among individuals of a population. It is of three types (a) **SNP** (single nucleotide polymorphism). (b) **VNTRs** (variable number tandem repeats) and (c) **RFLP** (Restriction fragment length polymorphism).

Translation. It is the biosynthesis of protein/polypeptide chain using mRNA as template. The amino acids are added in a sequence defined by the sequence of bases in the mRNA and in turn by DNA.

Bioinformatics. It is a combination of biology, information technology and computer science that deals with data storage, retrieval and analysis of sequences of bases in human genome using high speed computational devices.

Applications of Bioinformatics are (i) **Organisation of Biological Data.** As a requirement for bioinformatics, the available biological data has been organised. (ii) **Functional Genomics.** It provides information as to the presence or absence of alleles against various types of ailments in different ethnic groups. It will be helpful in treating diseases at the genetic level. (iii) **Proteomics.** Protein sequence databases or proteomics has an immense application in diagnostics, health care and drug research. (iv) **Medical Informatics.** Medical or clinical informatics studies, improves and invents various clinical technologies for better diagnosis and treatment of diseases.

TEXT QUESTIONS

One Mark Questions (With Answers)

1. Name two scientists who proposed the operon concept.
✓ Jacob & Monod (1961)
2. How gene and cistron are different ?
✓ Cistron is a part of gene that has a starting codon, terminal codon and sufficient codons to code a functional polypeptide chain. A gene can have many cistrons.
3. Name the two types of operons ?
✓ Inducible, repressible
4. Name two scientists who proved experimentally that DNA is the genetic material.
✓ Hershey and Chase.
5. Name the two purines of DNA molecule ?
✓ Adenine (A); Guanine (G)
6. Name the two pyrimidines of DNA molecule
✓ Cytosine (C), Thymine (T)
7. What are Variable Number Tandem Repeats or VNTRs ?
✓ These are short nucleotide repeats in the DNA that vary in number from person to person, but are inherited.
8. What is pluripotency ?
✓ It is the ability of a cell to develop any type of the cell in the animal body, for example, kidney cells or heart cells or nerve cells.
9. Why is hn RNA required to undergo splicing ? (CBSE 2009)
10. Which organic molecule other than protein can act as biocatalyst ? (CBSE 2010)
11. Name the enzyme involved in the continuous replication of DNA strand. Mention the polarity of the template strand. (CBSE 2010)
12. Mention two functions of the codon AUG. (CBSE 2011)
13. Mention the contribution of genetic maps in human genome project. (CBSE 2011)
14. Mention the role of codons AUG and UGA during protein synthesis. (CBSE 2013)
15. Name the enzyme and state its property that is responsible for continuous and discontinuous replication of two strands of a DNA molecule. (CBSE 2014)
16. Mention how does DNA polymorphism arise in a population. (CBSE 2014)
17. How is repetitive/satellite DNA separated from bulk genomic DNA for various genetic experiments? (CBSE 2014)
18. Why is it not possible for an alien DNA to become part of a chromosome anywhere along its length and replicate normally? (CBSE 2015)
19. What is cistron ? (CBSE 2015)
20. Retroviruses have no DNA. However, DNA of the infected host cell does possess viral DNA. How is it possible ? (CBSE 2015)
21. Name the transcriptionally active region of chromatin in a nucleus. (CBSE 2015)

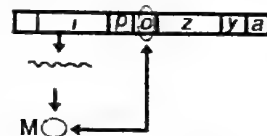
22. How does a degenerate code differ from an unambiguous one ?
 23. Write the function of RNA polymerase II.

(CBSE 2015)

(CBSE 2015)

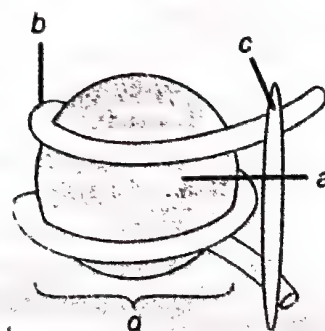
Two Mark Questions (With Sample Answers)

- What do you understand by the antiparallel arrangement of DNA strands?
 ✓ The two DNA chains are **antiparallel** that is, they run parallel but in opposite directions. In one chain the direction is $5' \rightarrow 3'$ while in the opposite one it is $3' \rightarrow 5'$ (Fig. 6.6). The two chains are held together by hydrogen bonds between their bases.
- Why replication is not continuous on the DNA template with $5' \rightarrow 3'$ direction ?
 ✓ Replication is not continuous on the other template because only a short segment of DNA strand can be built in $5' \rightarrow 3'$ direction due to exposure of a small stretch of template at one time.
- If DNA is damaged due to mutations, can it be repaired by DNA polymerase ? How?
 ✓ There is a separate repair mechanism for any damage caused to DNA due to mutation, UV exposure or mismatching that escapes proof-reading mechanism. A nick or break is caused by an endonuclease near the region of repair. DNA polymerase I removes the mismatched or wrong nucleotides if present and synthesises a correct replacement by using the intact strand as template. The newly formed segment is sealed by DNA ligase.
- Explain the dual function of AUG codon. Give the sequence of bases it is transcribed from and its anticodon.
 (CBSE 2009)
- (a) Name the molecule 'M' that binds with the operator.
 (b) Mention the consequences of such binding.
 (c) What will prevent the binding of the molecule 'M' with the operator gene ? Mention the event that follows.
 (CBSE 2009)
- Differentiate between a template strand and a coding strand of DNA.
 (CBSE 2009)
- Mention the role of ribosomes in peptide bond formation. How does ATP facilitate it ?
 (CBSE 2010)
- Write the full form of VNTR. How is VNTR different from probe ?
 (CBSE 2011)
- How do histones acquire positive charge ?
 (CBSE 2011)
- State the dual role of deoxyribonucleoside triphosphates during DNA replication.
 (CBSE 2011)
- (a) Draw a labelled diagram of a nucleosome.
 (b) Mention what enables histones to acquire positive charge.
 (CBSE 2012)
- State the function of the following in a prokaryote (i) tRNA (ii) rRNA.
 (CBSE 2012)
- (a) Name the scientist who suggested that the genetic code should be made of a combination of three molecules.
 (b) Explain the basis on which he arrived at this conclusion.
 (CBSE 2014)
- State the difference between the structural genes in the transcription unit of prokaryotes and eukaryotes.
 (CBSE 2014)
- Explain the two factors responsible for conferring stability to double helix structure of DNA.
 (CBSE 2014)
- Following are the features of genetic code. What does each one indicate ? _____ Stop codon, Unambiguous codon, Degenerate codon, Universal codon.
 (CBSE 2016)
- Describe the structure of a nucleosome.
 (CBSE 2017)
- Differentiate between the genetic codes given below :
 (a) Unambiguous and Universal. (b) Degenerate and Initiator.
 (CBSE 2017)

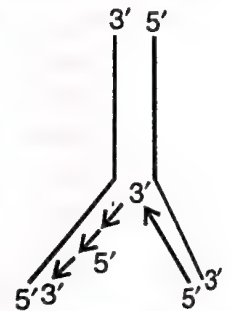
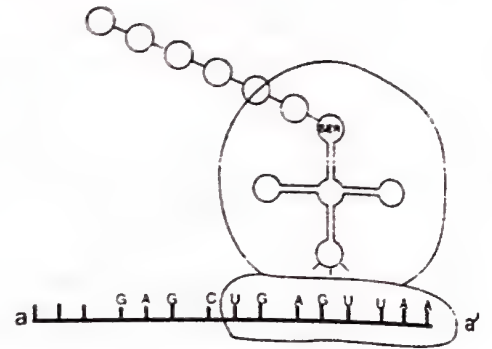


Three Mark Questions (Short Answer Type Answers)

- Draw a labelled schematic sketch of replication fork of DNA. Explain the role of enzymes involved in DNA replication.
 (CBSE 2009)
- (a) What is the diagram representing ?
 (b) Name the parts a, b and c.
 (c) In the eukaryotes the DNA molecules are organised within the nucleus. How is the DNA molecule organised in a bacterial cell in the absence of a nucleus ?
 (CBSE 2009)
- What are satellite DNA in a genome ? Explain their role in DNA finger printing.
 (CBSE 2009)



4. (a) Draw a schematic representation of the structure of a transcription unit and show the following in it. (i) Direction in which the transcription occurs. (ii) Polarity of the two strands involved. (iii) Template strand. (iv) Terminator. (CBSE 2009)
5. (a) In human genome which one of the chromosomes has the most genes and which one has the fewest ? (CBSE 2009)
- (b) Scientists have identified about 1.4 million single nucleotide polymorphs in human genome. How is the information of their existence going to help the scientists ? (CBSE 2009)
6. (a) Identify the polarity from a to a' in the diagram and mention how many more amino acids are expected to be added to this polypeptide chain.
- (b) Mention the DNA sequence coding for serine and the anticodon of tRNA for the same amino acid.
- (c) Why are some untranslated sequences of bases seen in mRNA coding for polypeptide? Where exactly are they present on mRNA ? (CBSE 2009)
7. In a series of experiments with *Streptococcus* and mice F. Griffith concluded that R-strain bacteria had been transformed. Explain. (CBSE 2010)
8. Describe the initiation process of transcription in bacteria. (CBSE 2010)
9. Describe the elongation process of transcription in bacteria. (CBSE 2010)
10. Describe the termination process of transcription in bacteria. (CBSE 2010)
11. (i) Name the enzyme that catalyses the transcription of hnRNA. (CBSE 2011)
- (ii) Why does the hnRNA need to undergo changes? List the changes hnRNA undergoes and where in the cell such changes take place ? (CBSE 2011)
12. Unambiguous, universal and degenerate are some of the terms used for the genetic code. Explain the salient features of each one of them. (CBSE 2011)
13. (a) Name the scientist who called tRNA an adapter molecule.
- (b) Draw a clover leaf structure of tRNA showing the following. (i) Tyrosine attached to its amino acid site. (ii) Anticodon for this amino acid in its correct site (codon for tyrosine is UCA).
- (c) What does actual structure of tRNA look like ? (CBSE 2011)
14. The base sequence in one of the strands of DNA is TAGCATGAT. (i) Give the base sequence of its complementary strand. (ii) How are these base pairs held together in a DNA molecule ? (iii) Explain the base complementary rule. Name the scientist who framed this rule. (CBSE 2011)
15. Why do you see two different types of replicating strands in the given DNA replication fork? Explain. Name these strands. (CBSE 2011)
16. List the salient features of double helix structure of DNA. (CBSE 2012)
17. How are the structural genes activated in the lac operon in *Escherichia coli* ? (CBSE 2012)
18. Describe the structure of a RNA polynucleotide chain having four different types of nucleotides. (CBSE 2013)
19. (a) Explain DNA polymorphism as the basis of genetic mapping of human genome.
- (b) State the role of VNTR in DNA finger printing. (CBSE 2013)
20. In a maternity clinic, for some reasons the authorities are not able to hand over the two new borns to their respective real parents. Name and describe the technique that you would suggest to sort out the matter. (CBSE 2013)
21. A burglar in a huff forgot to wipe off his blood stains from the place of crime where he was involved in a theft and fight. Name the technique which can help in identifying the burglar from the blood stains. Describe the technique. (CBSE 2013)
22. Explain the significance of satellite DNA in DNA fingerprinting technique. (CBSE 2015)
23. "A very small sample of tissue or even a drop of blood can help determine paternity". Provide a scientific explanation to substantiate the statement. (CBSE 2015)
24. (a) A DNA segment has a total of 1000 nucleotides, out of which 240 of them are adenine containing nucleotides. How many pyrimidine bases this DNA segment possesses ?



- (b) Draw a diagrammatic sketch of a portion of DNA segment to support your answer. (CBSE 2015)
25. Following the collision of two trains, a large number of passengers are killed. A majority of them are beyond recognition. Authorities want to hand over the dead to their relatives. Name a modern scientific method and write the procedure that would help in the identification of kinship. (CBSE 2015)
26. How was a heavy isotope of nitrogen used to provide experimental evidence to semi-conservative mode of DNA replication? (CBSE 2015)
27. Describe the experiment that helped demonstrate the semiconservative mode of DNA replication. (CBSE 2016)
28. A number of passengers were severely burnt beyond recognition during a train accident. Name and describe a modern technique that can help in handing over the dead to their relatives. (CBSE 2017)

Or

A criminal blew himself up in a local market when was chased by cops. His face was beyond recognition. Suggest and describe a modern technique that can help establish his identity. (CBSE 17)

29. (a) List the two methodologies which were involved in human genome project. Mention how they were used?
- (b) Expand 'YAC' and mention what was it used for. (CBSE 2017)

Five Mark Questions (Long Answer Type)

- (a) What did Meselson and Stahl observe when (i) They cultured *E. coli* in a medium containing $^{15}\text{NH}_4\text{Cl}$ for a few generations and centrifuged the contents? (ii) They transferred one such bacterium to the normal medium of NH_4Cl and cultured for two generations?
- (b) What did Meselson and Stahl conclude from this experiment? Explain with the help of diagrams.
- (c) Which is the first genetic material? Give reason in support of your answer. (CBSE 2009)
- How did Alfred Hershey and Martha Chase arrive at the conclusion that DNA is the genetic material? (CBSE 2010)
- (a) State the arrangement of different genes that in bacteria is referred to as operon.
- (b) Draw a Schematic labelled illustration of lac operon in a 'switched on' state.
- (c) Describe the role of lactose in lac operon. (CBSE 2010)
- Describe Frederick Griffith's experiment on *Streptococcus pneumoniae*. Discuss the conclusion he arrived at. (CBSE 2012)
- (a) Describe the process of synthesis of fully functional mRNA in a eucaryotic cell.
- (b) How is this process of mRNA synthesis different from that in prokaryotes? (CBSE 2012)
- (a) Write the conclusion drawn by Griffith at the end of his experiment with *Streptococcus pneumoniae*.
- (b) How did Avery, McLeod and McCarty prove that DNA was the genetic material. Explain. (CBSE 2013)
- (a) Write the specific features of genetic codon AUG.
- (b) Genetic code can be universal and degenerate. Write about them, giving one example of each.
- (c) Explain aminoacylation of the tRNA. (CBSE 2013)
- (a) Explain the process of DNA replication with the help of a schematic diagram. (b) In which phase of cell cycle does replication occur in eukaryotes? What would happen if cell division is not followed after DNA replication? (CBSE 2014)
- Describe how the lac operon operates both in the presence and absence of an inducer in *E. coli*. (CBSE 2014)
- How do mRNA, tRNA and ribosomes help in the process of translation? (CBSE 2015)
- Explain the process of transcription in prokaryotes. How is the process different in eukaryotes? (CBSE 2015)
- Describe Meselson and Stahl's experiment that was carried in 1958 on *E. coli*. Write the conclusion they arrived at after the experiment. (CBSE 2016)
- (a) Describe the process of transcription in bacteria.
- (b) Explain the processing of hnRNA needs to undergo before becoming functional mRNA in eukaryotes. (CBSE 2016)
- (a) Describe the series of experiments of F. Griffith. Comment on the significance of the results obtained.
- (b) State the contribution of Macleod, McCarty and Avery. (CBSE 2016)
- (a) Name the stage in the cell cycle where DNA replication occurs.
- (b) Explain the mechanism of DNA replication. Highlight the role of enzymes in the process.
- (c) Why is DNA replication said to be semiconservative? (CBSE 2016)

17. (a) How are the following formed and involved in DNA packaging in a nucleus of a cell ?
(i) Histone octamer (ii) Nucleosome (iii) Chromatin. (CBSE 2016)
(b) Differentiate between euchromatin and heterochromatin. (CBSE 2016)
18. Explain the role of lactose as an inducer in a *Lac* operon. (CBSE 2016)
19. List the criteria a molecule that can act as genetic material must fulfill. Which one of the criteria are best fulfilled by DNA or by RNA thus making one of them a better genetic material than the other ? Explain. (CBSE 2016)
20. (a) Describe the structure and function of a *t* RNA molecule. Why is it referred to as an adapter molecule ?
(b) Explain the process of splicing of *hn*RNA in a eukaryotic cell.

OR

Write the different components of a *lac* operon in *E. coli*. Explain its expression, while it is in 'open' state. (CBSE 2017)

21. (a) What is an operon ? (b) Explain how a polycistronic structural gene is regulated by a common promoter and a combination of regulatory genes in a *lac* operon. (CBSE 2017)
22. (a) Absence of lactose in the culture medium affects the expression of a *lac*-operon in *E. coli*. Why and how? Explain.
(b) Write two ways in which the gene expression is regulated in eukaryotes. (CBSE 2017)

Value Based Question

1. In a maternity clinic, for some reasons, two new borns got mixed up. How will it be possible to find out the identity of the neonates as to their real parents ?
✓ Genetic make up of a child is related to the genetic constitution of the parents. Two methods can be used to determine the identity of the babies as to their parents.
- (i) **Blood Grouping.** In many cases, matching of blood groups of the baby and the parents can give indication of their relationship, e.g., 'O' from 'O' and 'O' parents, no 'O' if any of the parents is 'AB', no 'A' or 'AB' if both the parents are of 'B' blood group.
- (ii) **DNA Finger Printing.** Comparison of VNTRs or RFLP of the baby with that of the parents provides fool proof method of determining the relationship.
2. Griffith factor was found to be DNA/gene by Avery *et al.* What values are depicted by the two discoveries?
✓ Griffith factor is a particulate material that could be picked up by a living cell from the dead remains of its relatives and develop the property of the same. The phenomenon is called **transformation**. It is now widely used in biotechnology.
- The work of Avery *et al* proved that Griffith factor is DNA or gene. They found DNA to be molecular basis of heredity.
- Both the discoveries indicated that DNA could be extracted from a cell and passed into another cell. Today gene transfer is being carried out in the preparation of genetically modified organisms, replacement of defective genes (gene therapy) and production of important biochemicals.

Multiple Choice Questions (With Answers)

- (1) Number of triplet codons having all the three bases same in 64 triplet codons is (a) 12 (b) 8 (c) 6 (d) 4. (AMU 2009)
- (2) Largest gene in human is (a) Oncogene (b) Tumour suppresser gene (c) Dystrophin (d) Insulin gene. (Kerala 2009)
- (3) Whose experiments cracked DNA and discovered triplet nature of genetic code. (a) Nirenberg and Mathaei (b) Beadle and Tatum (c) Hershey and Chase (d) Morgan and Sturtevant. (CBSE 2009)
- (4) DNA synthesis during replication is (a) discontinuous (b) continuous (c) semi-discontinuous (d) none of the above. (MP PMT 2010)
- (5) Which one of the following does not follow the central dogma of molecular biology (a) *Mucor* (b) *Chlamydomonas* (c) HIV (d) Pea. (CBSE 2010)
- (6) What is special of base sequence of two strands of DNA segment
5' — GAATTC — 3'
3' — CTTAAG — 5'

- (a) Start condition at 5' end (b) Palindromic sequence of base (c) Replication completed (d) Deletion mutation. (CBSE 2011)

- (7) Which one is not a part of transcription unit in DNA ? (a) The inducer (b) Promoter (c) Terminator (d) Structural gene. (CBSE 2012)
- (8) Which enzyme (s) will be produced in a cell in which there is a nonsense mutation in the *lac y* gene (a) Lactose permease and transacetylase (b) Lactose permease (c) Transacetylase (d) β - galactosidase. (NEET 2013)
- (9) Commonly used vectors used for human genome sequencing were (a) BAC and YAC (b) Expression vectors (c) T-DNA (d) T/A cloning vectors. (CBSE 2014)
- (10) Which one is not applicable to RNA ? (a) Complementary base pairing (b) 5' phosphoryl and 3' hydroxyl ends (c) Heterocyclic nitrogenous bases (d) Chargaff's rule. (CBSE 2015)
- (11) Which of the following is not required for any of the techniques of DNA finger printing available at present (a) DNA-DNA hybridisation (b) polymerase chain reaction (c) zinc finger analysis (d) restriction enzymes. (NEET-I-2016)
- (12) During DNA replication, Okazaki fragments are used to elongate (a) the lagging strand towards replication fork (b) the leading strand away from replication fork (c) the lagging strand away from the replication fork (d) the leading strand towards replication fork. (NEET 2017)
- (13) Which of the following RNAs should be most abundant in animal cell? (a) tRNA (b) mRNA (c) miRNA (d) rRNA. (NEET 2017)
- (14) The association of histone H_1 with a nucleosome indicates that (a) DNA replication is occurring (b) the DNA is condensed into a chromatin fibre (c) the DNA double helix is exposed (d) transcription is occurring. (NEET 2017)
- (15) DNA replication in bacteria occurs (a) within nucleolus (b) prior to fission (c) just before transcription (d) during S phase. (NEET 2017)
- (16) If there are 999 bases in an RNA that code for a protein with 333 amino acids, and the base at position 901 is deleted such that the length of the RNA becomes 998 bases, how many codons will be altered ? (a) 11 (b) 33 (c) 333 (d) 1. (NEET 2017)
- (17) The final proof for DNA as the genetic material came from the experiments of (a) Hershey and Chase (b) Avery, MacLeod and McCarty (c) Hargobind Khorana (d) Griffith. (NEET 2017)
- (18) DNA fragments are (a) positively charged (b) negatively charged (c) neutral (d) either positively or negatively charged depending on their size. (NEET 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given, one is Assertion (A) and the other is Reason (R). For the (A) and (R) statements, mark the correct answer as

- (a) If both A and R are true and R is correct explanation of A.
- (b) If both A and R are true and R is not correct explanation of A
- (c) If A is true and R is false (d) If both A and R are false

1. **Assertion.** Persons suffering from haemophilia fail to produce blood clotting factor VIII.
Reason. Prothrombin producing platelets are in very low concentration.
(A) (B) (C) (D) (AIIMS 2008)
2. **Assertion.** Replication and transcription occur in the nucleus but translation takes place in the cytoplasm.
Reason. mRNA is transferred from the nucleus into cytoplasm where ribosomes and amino acids are available for protein synthesis.
(A) (B) (C) (D) (AIIMS 2008)
3. **Assertion.** One codon may code or more than one amino acid.
Reason. A codon is degenerate and ambiguous.
(A) (B) (C) (D) (AIIMS 2014)

ANSWERS

Multiple Choice Questions

- (1) —d (2) —c (3) —a (4) —c (5) —c (6) —b (7) —a (8) —d (9) —a (10) —d
(11) —c (12) —c (13) —d (14) —b (15) —b (16) —b (17) —a (18) —b

Assertion and Reason Type Questions

- (1) —C (2) —A (3) —D

What is Life ?

Life is an inherent capacity that an organism possesses to maintain and reproduce itself. Philosophers have different views about life. Here, we study the biological aspects of life.

Events in the History of Life

The history of life comprises two events — first, the origin of life and second, the evolution of life (the mechanism involved in the changes of living organisms through time).

Let us first know how were the universe and earth originated ?

Origin of Universe

There are several theories regarding the origin of universe but the most accepted theory is big-bang* theory.

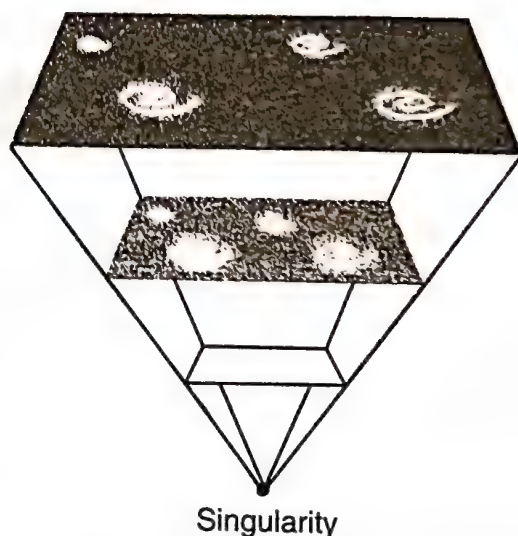


Fig. 7.1. The Big Bang

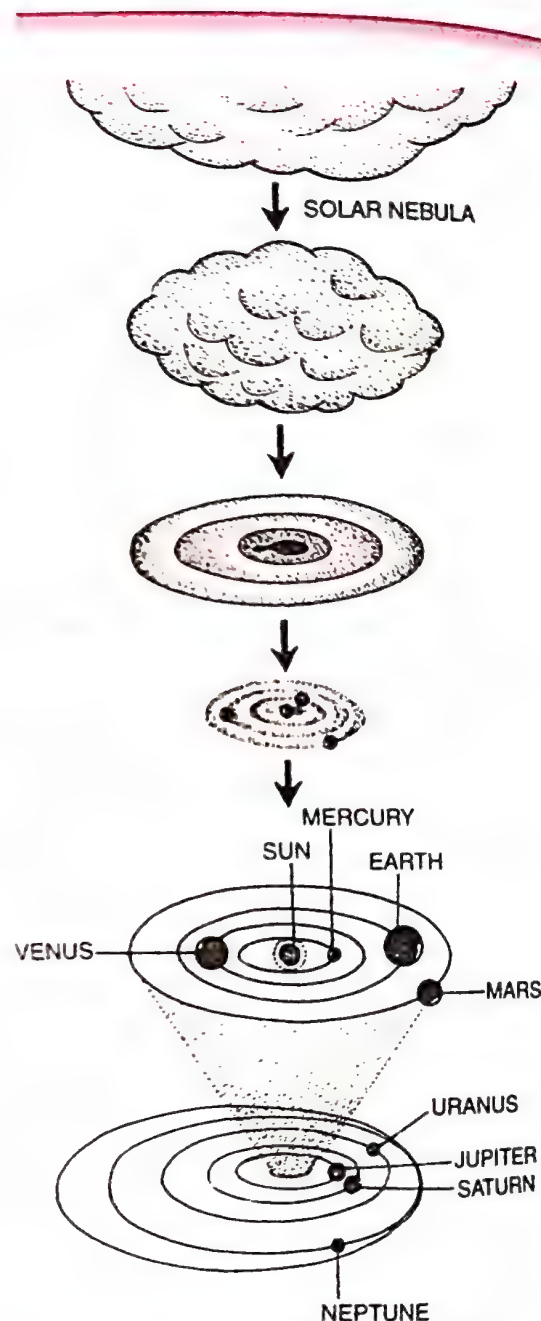


Fig. 7.2. Schematic representation of origin of our solar system.

Big-bang Theory. This theory was proposed by Abbe Lemaitre in 1931. According to big-bang theory about** 20 billion years ago, cosmic matter was in a condensed form. A fiery** explosion took place which broke the condensed matter and scattered its fragments into space at an enormous velocity making a “big bang” sound and thus the theory came

* Bang— sudden, loud noise (DHAMAKA in Hindi)

** Fiery— looking like fire, flaming.

to be known as big bang theory. Immediately after the explosion, the universe (*L. universum* – whole world) or the cosmosa (Gk. *Kosmos* – world) expanded rapidly from a size of a pin to about 2,000 times the size of the sun.

Our Solar System

Nebular Hypothesis is one of the most popular hypotheses to explain the origin of solar system. Nebular hypothesis was first proposed by **Kant** in 1755. **Laplace** revised it in 1796. According to this hypothesis our solar system was probably created about 4.5 to 5 billion years ago when the gaseous cloud called **solar nebula** was formed. As the cloud condensed the central mass formed the **sun** and the peripheral celestial bodies (bodies in the sky) form planets, satellites, asteroids, meteors and comets forming the **solar system**. Thus the sun along with its peripheral celestial bodies comprise the solar system.

The solar system comprises the sun, eight planets and their satellites (moons), asteroids, comets, meteors and meteorites.

The Sun. The sun was formed about 4.6 billion years ago. The sun is one of the stars and nearest to earth. The sun is the ultimate source of heat and light. The hottest place in the solar system is the centre (core) of the sun.

Galaxies. A galaxy is a large system of stars, dust and gas held together by gravity. Milky Way or Akash Ganga visible in the sky during night is a galaxy. Solar system is located in this galaxy.

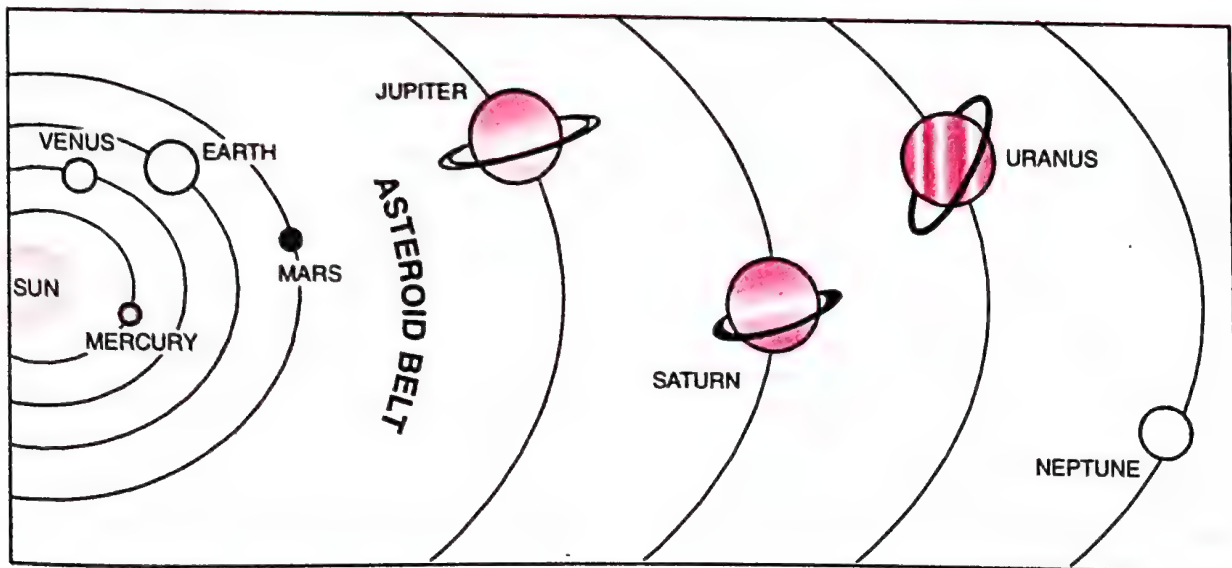


Fig. 7.3. Solar system showing inner and outer planets.

Planets. There are eight planets which were formed about 4.6 billion years ago in our solar system. They are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. Till August 2006, Pluto was also considered a planet but it was disqualified and now may be called "Dwarf Planet".

Satellites or Moons. The satellites or moons are the small bodies that revolve round their mother planets in the solar system. The satellites or moons are as follows — earth

has 1, Mars 2, Jupiter 67, Saturn 53, Uranus 27, Neptune 13, Mercury and Venus do not have any satellite or Moon.

Asteriods. Asteriods are small rocky bodies that move around the sun mostly between Mars and Jupiter.

Comets. Comets are small icy bodies that orbit around the sun. A comet has two distinct parts—a head and a tail.

Meteors. They are tiny particles of dust left over from comets which produce streaks of light as they enter the Earth's atmosphere with great speed and burn out.

Meteorites. They are stony or metallic objects that have fallen to the earth from outer space.

Study of origin of universe is called **cosmogony** while the study of universe is known as **cosmology**.

Our Earth

The earth was supposed to have been formed about 4.5 billion years ago which was later differentiated into three main parts :—

1. **Crust.** It is the outer-most solid, rocky surface of the earth.

2. **Mantle.** It is the middle part of earth which is solid and consists of iron and magnesium silicates.

3. **Core.** It is the central part of earth, which is differentiated into semisolid **outer core** and solid **inner core**.

Earth originally had only two components, solid mass called **lithosphere** surrounded by a gaseous envelope termed **atmosphere**. The liquid component, known as **hydrosphere**, appeared later when the earth cooled down to a temperature below 100°C .

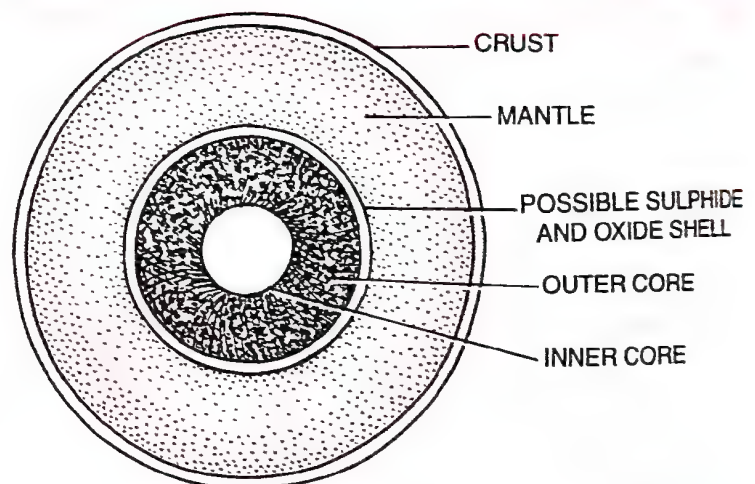


Fig. 7.4. Earth in section.

Differences between Primitive and Recent Atmosphere of the Earth

<i>Primitive Atmosphere</i>	<i>Recent Atmosphere</i>
1. It was reducing (without free oxygen) atmosphere.	1. It is oxidizing (with free oxygen) atmosphere.
2. Its most common element was hydrogen.	2. It has about 20.95% oxygen and less than 0.04% of hydrogen.
3. It had no ozone layer therefore, ultraviolet radiation freely reached the earth.	3. It has thick ozone layer that prevents the ultraviolet radiation reaching the earth.
4. It was very hot.	4. It has moderate temperature.
5. It was favourable to origin of life. It allowed chemical evolution.	5. It is not favourable to origin of life. It does not allow chemical evolution.

ORIGIN OF LIFE

Theories of the Origin of Life

Some important theories about origin of life are described below.

Ancient Theories of Origin of Life

Following ancient theories are important to mention.

1. Theory of Special Creation.

The greatest supporter of this theory was **Father Suarez**. According to this theory life was created by supernatural power. According to Bible the first man, **Adam** and the first woman, **Eve** were created by God. According to *Hindu* mythology the world was created by God **Brahma**. The first man was **Manu** and the first woman was **Shradha**. Special creation theory lacks scientific evidences, on account of which it is *not accepted*.

2. Theory of Spontaneous Generation (Abiogenesis or Autogenesis).

This theory states that life originated from nonliving things in a spontaneous manner. This concept was held by early Greek philosophers like **Thales**, **Anaximander**, **Xanophanes**, **Empedocles**, **Plato**, **Aristotle**, etc. In ancient **Egypt**, it was believed that the mud of the **Nile** could give rise to frogs, toads, snakes, mice and even crocodiles when warmed by the sun. **Van Helmont** (1577–1644) held that human sweat and wheat grains could give rise to organisms. He placed a dirty shirt in a receptacle containing wheat bran and found that after 21 days the gases from the shirt and wheat had formed living mice. These beliefs have no scientific grounds and hence are *discarded*.

Evidences against the Theory of Spontaneous Generation. The theory of spontaneous generation was disproved by many scientists of 17th, 18th and 19th centuries. They proved that new organisms can be formed from pre-existing ones, i.e., *omnis vivum ex ovo or vivo* ('**Biogenesis**' of Harvey and T. H. Huxley). Noted scientists who experimentally challenged the theory were **Francesco Redi**, **Lazzaro Spallanzani** and **Louis Pasteur**.



Francesco Redi



Lazzaro Spallanzani

(i) Redi's Experiment.

Francesco Redi, took the flesh and cooked it so that no organisms were left alive. Then he placed flesh in three jars, of which, one was uncovered, the second was covered with parchment and the third one was covered with fine muslin. He kept these jars for a few days and observed that maggots developed only in the uncovered jar though the flies also visited other jars (Fig. 7.5).

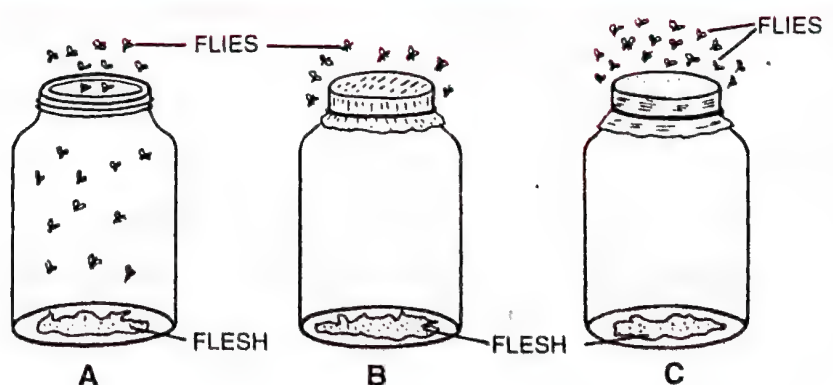


Fig. 7.5. Redi's experiment. A, Uncovered Jar. B, Jar covered with parchment. C, Jar covered with muslin.

(ii) **Spallanzani's Experiment.** Spallanzani disproved the spontaneous generation of microorganisms. He experimented that animal and vegetable broths boiled for several hours and soon after sealed, were never infested with microorganisms. From this experiment he concluded that high temperature had killed all living organisms in the broths and without them life could not appear. When the broths were left exposed to air, were soon invaded by microorganisms.



Louis Pasteur

(iii) **Pasteur's Experiment.** Louis Pasteur took broths in a long necked flask and then he bent the neck of the flask. He boiled the broths in the flask to kill any microorganisms that might be present in them. The curved neck acted as a filter. If the flask with 'swan neck' (curved neck) is kept for months together, no life appeared, as the germ laden dust particles in the air were trapped by the curved neck which serves as filter. If the swan neck was broken off, the broths developed colonies of *moulds* and *bacteria*. Thus, he showed that the source of the micro-organisms for fermentation or putrefaction such as for milk, sugar and wine, etc., was the air and the organisms did not arise from the nutrient media.

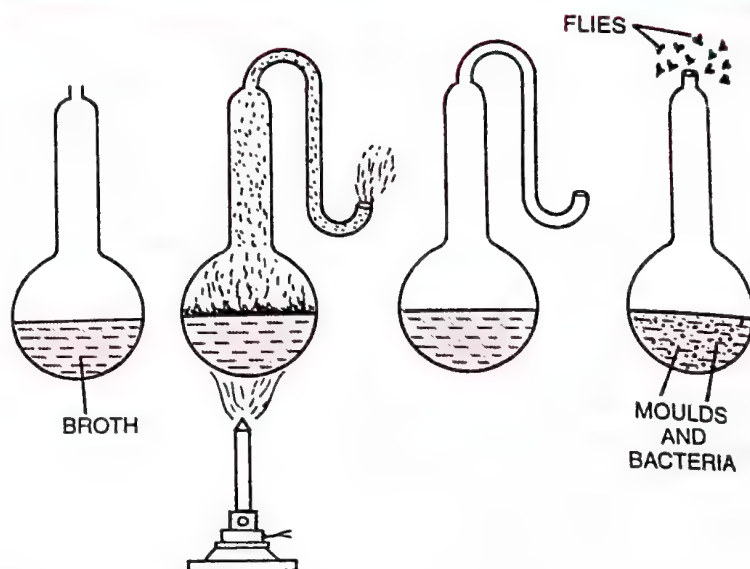


Fig. 7.6. Different Stages of Pasteur's Experiment.

Thus Louis Pasteur (famous for "**Germ Theory of Disease and Immunology**") finally disapproved abiogenesis and proved biogenesis.

But according to **biogenesis**, life originated from pre-existing life which does not explain the origin of life. So biogenesis is also disapproved.

3. Theory of Panspermia or Cosmozoic Theory or Spore Theory

This theory was proposed by **Richter** (1865). According to this theory, '**protoplasm**' reached the earth in the form of spores or germs or other simple particles from some unknown part of the universe with the cosmic dust, and subsequently evolved into various forms of life. **Helmholz** (1884) speculated that 'protoplasm' in some form reached the earth with falling meteorites. **Arrhenius** (1908, Nobel Prize Winner of 1903 in Chemistry) postulated the (= **Panspermia Theory**) and stated that organisms existed throughout the universe and their spores etc., could freely travel through space from one star to the others. In fact, panspermia theory is the alternative name of cosmozoic theory.

Evidences against Cosmozoic Theory. Living matter cannot survive the extreme cold, dryness and ultra-violet radiation from the sun required to be crossed for reaching the earth.

4. Theory of Eternity of Life.

This theory was proposed by **Preyer** in 1880. According to this theory, different types of living beings have always existed on earth and shall continue to exist forever, changing only in form.

Evidence Against Theory of Eternity of Life. It is accepted that earth had not always existed. If life is eternal, where did it exist before this planet was formed.

5. Theory of Catastrophism.

Georges Cuvier (1769-1832), Father of “Modern Palaeontology” and **Orbigney** (1802-1837) were the chief advocates of this theory. According to this theory **cataclysms** (great destruction) or **catastrophic** (concerning disastrous event) **revolution** occurs upon earth from time to time which completely destroys all organisms (living beings). New organisms, then, suddenly form from inorganic matter. Each creation consists of life quite different from that of the previous one. In fact, this theory is merely a modification of theory of special creation. This theory is also not accepted.

6. Modern Theory or Oparin-Haldane Theory of Origin of Life

According to this theory life originated on early earth through physico-chemical processes of atoms combining to form molecules, molecules in turn reacting to produce inorganic and organic compounds. Organic compounds interacting to produce all types of macromolecules which organised to form the first living system or cells.

Thus according to this theory ‘life’ originated upon our earth spontaneously from non-living matter. First inorganic compounds and then organic compounds were formed in accordance with everchanging environmental conditions. This is called chemical evolution which cannot occur under present environmental conditions upon earth. Conditions suitable for origin of life existed only upon primitive earth.

Oparin-Haldane theory is also called **chemical theory** or **naturalistic theory**.

A.I. Oparin (1894–1980) was a Russian Scientist. He published his book “The origin of Life” in 1936 and an English edition in 1938. **J.B.S. Haldane** (1892–1964) was born in England but migrated to India in July 1957 and settled in Bhubaneswar, Orissa. He was biologist, biochemist and geneticist. Both Oparin (1938) and Haldane (1929) gave similar views regarding the origin of life.

Modern views regarding the origin of life include chemical evolution and biological evolution :



J.B.S. Haldane

A. Chemical Evolution (Chemogeny)

1. **The Atomic Phase.** Early earth had innumerable atoms of all those elements (*e.g.*, hydrogen, oxygen, carbon, nitrogen, sulphur, phosphorus, *etc.*) which are essential for the formation of protoplasm.

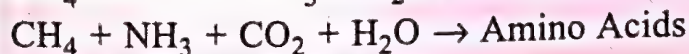
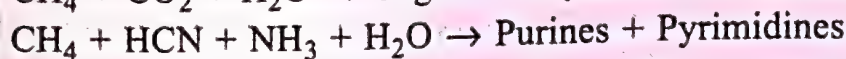
2. **Formation of Simple Molecules.** Free atoms combined to form simple molecules such as H_2 (Hydrogen), N_2 (Nitrogen), H_2O (Water vapour), CH_4 (Methane), NH_3 (Ammonia), CO_2 (Carbon dioxide). Hydrogen atoms were most numerous and most reactive in primitive atmosphere. First hydrogen atoms combined with all oxygen atoms to form water and leaving no free oxygen. Thus primitive atmosphere was **reducing atmosphere** (without free oxygen) unlike the present oxidising atmosphere (with free oxygen).

Hydrogen atoms also combined with nitrogen, forming **ammonia** (NH_3). So water and ammonia were probably the first molecules of primitive earth.

3. **Formation of Simple Organic Molecules (Monomers).** The early simple molecules interacted and produced simple organic molecules such as **simple sugars** (*e.g.*,

ribose, deoxyribose, glucose, etc.), **nitrogenous bases** (e.g., purines, pyrimidines), **amino acids, glycerol, fatty acids**, etc.

Torrential rains must have fallen. As the water rushed down, it must have dissolved away and carried with it salts and minerals, and ultimately accumulated in the form of oceans. Thus ancient oceanic water contained large amounts of dissolved NH_3 , CH_4 , HCN , nitrides, carbides, various gases and elements.



Some external sources must have been acting on the mixture for reactions. These external sources might be (i) *solar radiations* such as ultra-violet light, X-rays, etc., (ii) energy from *electrical discharges* like lightning, (iii) *high energy radiations* are other sources of energies (probably unstable isotopes on the primitive earth). There was no ozone layer in the atmosphere. A soup-like broth of chemicals formed in oceans of the early earth from which living cells are believed to have appeared, was termed by J.B. Haldane (1920) as '**prebiotic soup**' (also called '**hot dilute soup**'). Thus the stage was set for combination of various chemical elements. Once formed, the organic molecules accumulated in water because their degradation was extremely slow in the absence of any life or enzyme catalysts.



Stanley Miller



Harold C. Urey.

Miller's Experiment

Stanley Miller in 1953, who was then a graduate student of **Harold Urey** (1893–1981) at the University of Chicago, demonstrated it clearly that ultra-violet radiation or electrical discharges or heat or a combination of these can produce complex organic compounds from a mixture of methane (CH_4), ammonia (NH_3), hydrogen (H_2) and water vapour. The ratio of methane, ammonia and hydrogen in Miller's experiment was 2 : 1 : 2.

Miller circulated four gases— **methane, ammonia, hydrogen and water vapour** in an air tight apparatus and passed electrical discharges from electrodes at 800°C . He passed the mixture through a condenser.

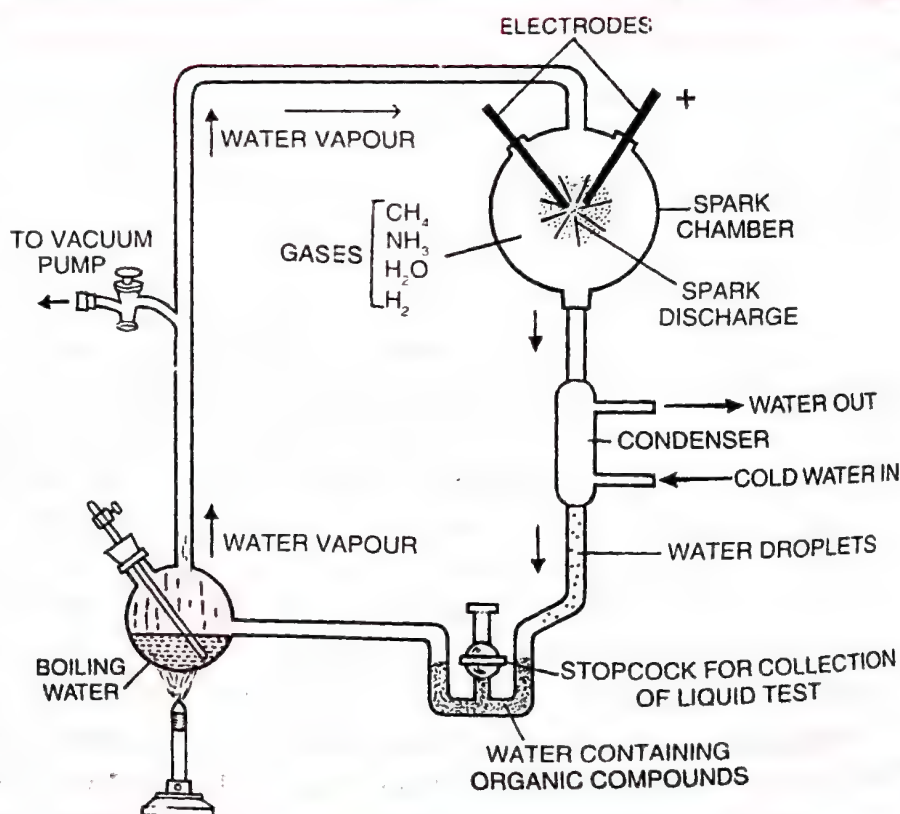


Fig. 7.7. Miller's Experiment.

He circulated the gases continuously in this way for one week and then analysed the chemical composition of the liquid inside the apparatus. He found a large number of simple organic compounds including some amino acids such as **alanine**, **glycine** and **aspartic acid**. Miller conducted the experiment to test the idea that organic molecules could be synthesized in a reducing environment.

Other substances, such as urea, hydrogen cyanide, lactic acid and acetic acid were also present. In another experiment Miller circulated the mixture of the gases in the same way but he did not pass the electric discharge. He could not get the significant yield of the organic compounds.

4. Formation of Complex Organic Molecules (Macromolecules). A variety of amino acids, fatty acids, hydrocarbons, purines and pyrimidine bases, simple sugars and other simple organic molecules accumulated in the ancient seas. In the primaeval atmosphere electrical discharge, lightning, solar energy, ATP and polyphosphates might have provided the source of energy for polymerisation reactions of organic synthesis. **Sidney W. Fox** of the university of Miami has demonstrated that if a nearly dry mixture of amino acids is heated, polypeptide molecules are synthesized. Similarly simple sugars could form **polysaccharides** and fatty acids could combine to produce **fats**. Amino acids could form **proteins**, when other factors were involved. Thus the small simple organic molecules combined to form large complex organic molecules, *e.g.*, amino acid units joined to form polypeptides and proteins, simple sugar units combined to form polysaccharides, fatty acids and glycerol united to form fats, sugars, nitrogenous bases, and phosphates combined into **nucleotides** which polymerized into **nucleic acids** in the ancient oceans.

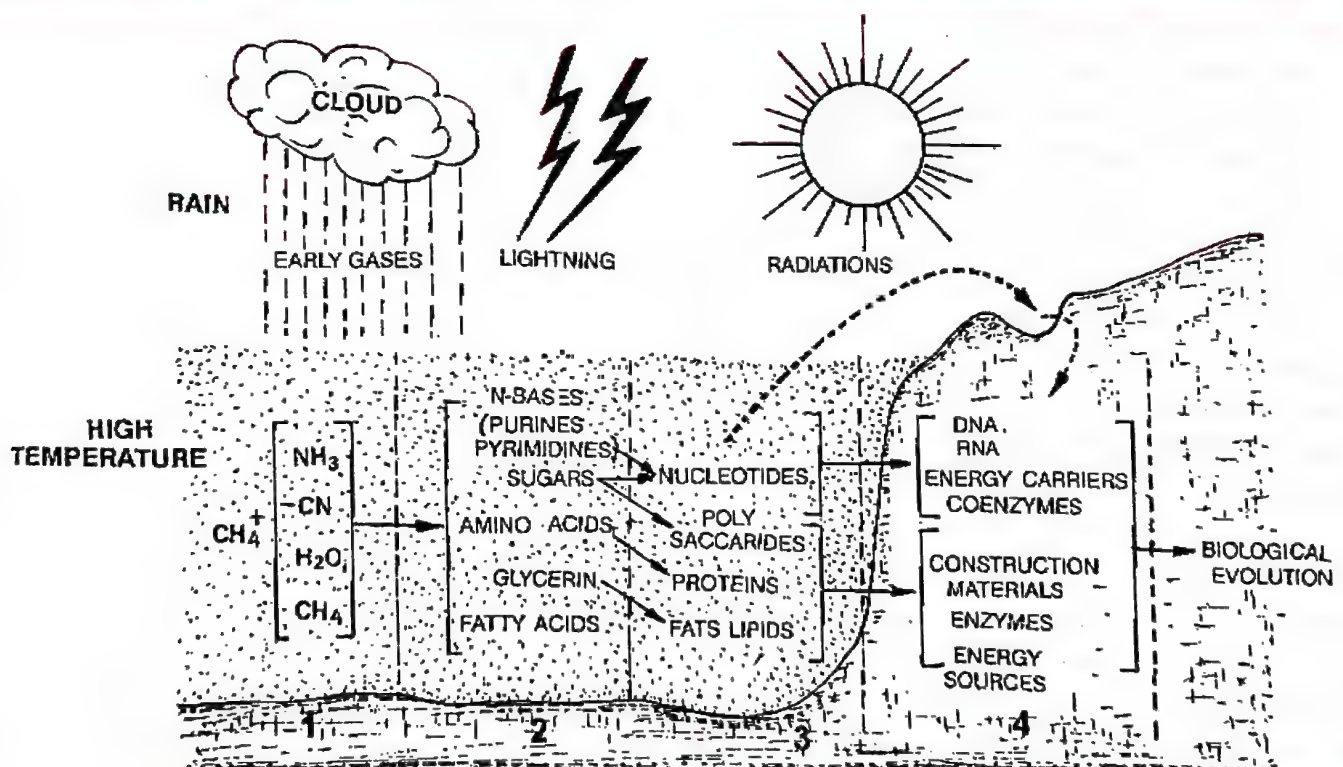
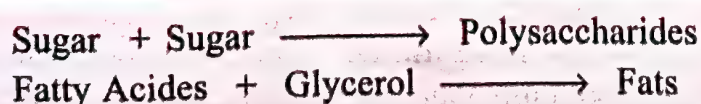
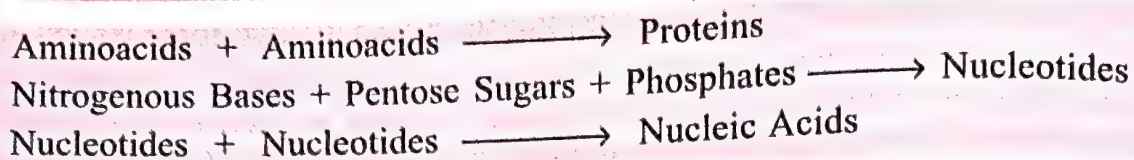


Fig. 7.8. Chemical evolution on early earth.





B. Biological Evolution (Biogeny)

Conditions for the Origin of Life. For origin of life, atleast three conditions are needed.

- There must have been a supply of replicators, *i.e.*, self-producing molecules.
- Copying of these replicators must have been subject to error through mutation.
- The system of replicators must have required a continuous supply of free energy and partial isolation from the general environment.

The high temperature in early earth would have fulfilled the requirement of mutation.

1. **Isolating Organic Molecules — Coacervates and Microspheres.** Two hypotheses are proposed for the formation of **prebionts** nonliving structures that led to the formation of the first living cells from which the more complex cells have today evolved.

(i) **Coacervates.** The first hypothesis was proposed by **Oparin**. According to this hypothesis early prebionts could have been coacervates. Oparin gave the term coacervates. Oparin speculated that a prebiont consisted a carbohydrates, proteins, lipids and nucleic acids that accumulated to form a **coacervate**. Such a structure could have consisted of a collection of organic macromolecules surrounded by a film of water molecules. This arrangement of water molecules, although not a membrane, could have functioned as a physical barrier between the organic molecules and their surroundings. They could selectively take in materials from their surroundings and incorporate them into their structure.

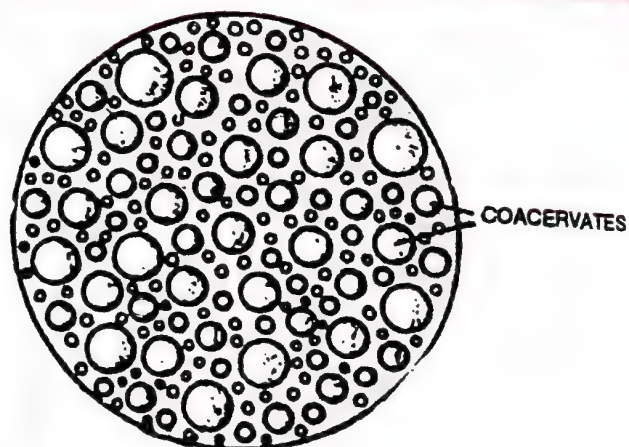


Fig. 7.9. Coacervates of Oparin.

Coacervates have been synthesized in the laboratory. Some coacervates contain enzymes that direct a specific type of chemical reaction. Because they lack a definite membrane, no one claims coacervates are alive. They have the ability to increase in size.

(ii) **Microspheres.** An another hypothesis is that early protocell could have been a **microsphere**. A microsphere is a nonliving collection of organic macromolecules with double layered outer boundary. The term microsphere was given by **Sidney W. Fox**. Sidney Fox demonstrated the ability to build microspheres from **proteinoids**. **Proteinoids** are protein like structures consisting of branched chains of amino acids. Proteinoids are formed by the dehydration synthesis of amino acids at a temperature of 180°C. Fox, from the University of Miami, showed that it is feasible to combine single amino acids into polymers of proteinoids. He also demonstrated the ability to build microspheres from these proteinoids. Fox observed small spherical cell-like units that had

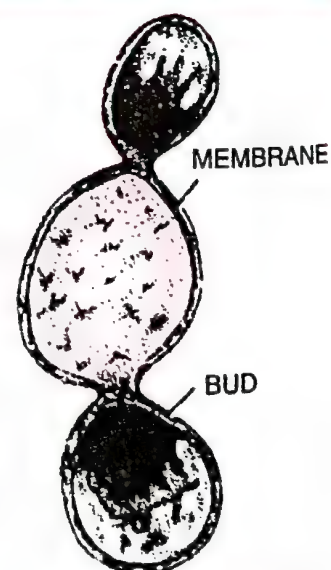


Fig. 7.10. Diagram showing budding in microsphere.

arisen from aggregations of proteinoids. These molecular aggregates were called **proteinoid microspheres**. *The first non-cellular forms of life could have originated 3 billion years back. They would have been giant molecules (RNA, Proteins, Polysaccharides etc.).* These capsules reproduced their molecules perhaps.

Microspheres can be formed when proteinoids are placed in boiling water and slowly allowed to cool. Microspheres swell or shrink depending on the osmotic potential in the surrounding solution. Using ATP as a source of energy, microspheres can direct the formation of polypeptides and nucleic acids. They have the ability of motility, growth, binary fission into two particles and a capacity of reproduction by budding and fragmentation. Superficially, their budding resembles with those of bacteria and fungi.

According to some investigators, microspheres can be considered first living cells.

2. Origin of Prokaryotes. Prokaryotes were originated from protocells about 3.5 billion years ago in the sea. The atmosphere was **anaerobic** because free oxygen was absent in the atmosphere. Prokaryotes do not have nuclear membrane, cytoskeleton or complex organelles. They divide by binary fission. Some of the oldest known fossil cells appear as parts of **stromatolites**. Stromatolites are found today from sediments and photosynthetic prokaryotes (mainly filamentous cyanobacteria— blue green algae).

3. Evolution of Modes of Nutrition

(i) **Heterotrophs.** The earliest prokaryotes presumably obtained energy by the fermentation of organic molecules from the sea broth in oxygen free atmosphere (reducing atmosphere). They required readymade organic material as food and thus they were **heterotrophs**.

(ii) **Autotrophs.** Due to rapid increase in the number of heterotrophs the nutrient from sea water began to disappear and gradually exhausted. That led to the evolution of autotrophs. These organisms were capable of producing their own organic molecules by chemosynthesis or photosynthesis.

(a) **Chemoautotrophs.** Drop in temperature stopped synthesis of organic molecules in the sea water. Some of the early prokaryotes got converted into **chemoautotrophs** which prepared organic food by using energy released during certain inorganic chemical reactions. These **anaerobic chemoautotrophs** were like present anaerobic bacteria. They released CO_2 in the atmosphere.

(b) **Photoautotrophs.** Evolution of chlorophyll molecule enabled certain protocells to utilize light energy and synthesize carbohydrates. These were **anaerobic photoautotrophs**. They did not use water as a hydrogen source. They were similar to present day sulphur bacteria in which hydrogen sulphide split into hydrogen and sulphur. Hydrogen was used in food manufacture and sulphur was released as a waste product.

Aerobic photoautotrophs used water as a source of hydrogen and carbon dioxide as source of carbon to synthesize carbohydrate in the presence of solar energy. The first aerobic photoautotrophs were **cyanobacteria** (blue green algae) like forms which had chlorophyll. They released oxygen in the atmosphere as the by product of photosynthesis. The main source of genetic variation was mutation.

Oxygen Revolution. As the number of photoautotrophs increased, oxygen was released in the sea and atmosphere. Free oxygen then reacted with methane and ammonia present in the primitive atmosphere and transformed methane and ammonia into carbon dioxide and free nitrogen.





The oldest fossil belonging to blue green algae, named *Archaeospheroides barbertonensis* which is 3.2 billion years old. Oxygen releasing prokaryotes first appeared atleast 2.5 billion years ago.

4. **Formation of Ozone Layer.** As oxygen accumulated in the atmosphere, the ultra-violet light changed some of oxygen into ozone.



The ozone formed a layer in the atmosphere, blocking the ultraviolet light and leaving the visible light as the main source of energy.

The first cellular form of life did not possibly originate till about 200 million years ago. These were probably single cells.

5. **Origin of Eukaryotes.** The eukaryotes developed from primitive prokaryotic cells about 1.5 billion years ago. There are two views regarding the origin of eukaryotes.

(i) **Symbiotic Origin.** According to Margulis (1970-1981) of Boston University, some anaerobic predator host cells engulfed primitive aerobic bacteria but did not digest them. These aerobic bacteria established themselves inside the host cells as symbionts. Such predator host cells became the first eukaryotic cells. The predator host cells that engulfed aerobic bacteria evolved into **animal cells** while those that captured both aerobic bacteria and blue-green algae became **eukaryotic plant cells**. The aerobic bacteria established themselves as **mitochondria** and blue green algae as **chloroplasts**.

(ii) **Origin by Invagination.** According to this view cell organelles of eukaryotic cells might have originated by invagination of surface membrane of primitive prokaryotic cells.

Origin of Multicellular Organisms

Once the unicellular organisms were developed the cells could gather to form colonies. Later **cell differentiation** occurred to form the multicellular organisms. The latter gave rise to all the different forms of life by gradual modification over the ages. The advantage of multicellularity is based on **division of labour** between the component cells.

Three major domains of life was proposed by Carl Woese includes **Eubacteria**, **Archaea** and **Eucarya**.

Major Events in Origin of Life

Event	Time
Origin of Universe	20 billion years
Our Solar System	4.5 to 5 billion years
Origin of Earth	Approx. 4.5 billion years
Origin of Earliest Prokaryotes	3.5 billion years
Origin of Oxygen releasing Prokaryotes	2.5 billion years
Origin of Eukaryotes	1.5 billion years
Origin of simple land plants	45.9 million years
Origin of Mammals	220 million years

Summary of Origin of Life

Free Atoms — — — — —	H, C, N, etc.
↓	
Simple molecules — — — — —	H ₂ , H ₂ O, CH ₄ , NH ₃ , CO ₂ , etc.
↓	
Simple organic molecules — — — — —	CH ₄ , CO ₂ , H ₂ O → Sugar, Fatty acids, Glycerol CH ₄ , CO ₂ , NH ₃ → Amino acids CH ₄ , H ₂ O, NH ₃ , HCN → Nitrogenous bases (Purines, Pyrimidines)
↓	
Complex organic molecules — — — — —	Sugar + Sugar + Sugar → Polysaccharides Fatty acids + Glycerol → Fats Amino acid + Amino acid → Proteins Nitrogen bases + Pentose Sugars + Phosphates → Nucleotides, Nucleotides + Nucleotides → Nucleic acids Capable of growth. Microspheres could undergo fission and budding
↓	
Coacervates or Microspheres — — — — —	
↓	
Free gene — — — — —	Self replicating nucleoprotein complex
↓	
Earliest cells — — — — —	Lipid-protein membrane-bound unit with enzyme controlled metabolism and nucleic acid regulation but lacked organized nucleus. They were heterotrophs
↓	
Prokaryotes — — — — —	Unicellulars, cells did not have distinct nucleus and cell organelles. They had evolved chemoautotrophism and photoautotrophism (mostly anaerobic).
↓	
Eukaryotes — — — — —	Cells with distinct nucleus and cell organelles. It is assumed that eukaryotic cells evolved from prokaryotic cells either by (i) symbiotic origin or (ii) origin by invagination
↓	
Origin of Multicellular organisms	Either by failure of separation of daughter cells after cell division or by aggregation of cells (i) Photosynthetic, e.g., Plants (ii) Heterotrophic, e.g., Animals

Where Life Originated ? Life originated in the ocean.

Life on Other Planets

Many scientists believe that life may have originated on some other planets as well. It is obvious that 'life' could have originated upon other planets and stars having conditions approximately similar to those of the primitive earth. Of the planets, only **Mars**, is supposed to have conditions suitable for sustaining life, although no evidence of life has yet been found by the scientists.

EVOLUTION

Evolution of Life Forms — A Theory

The theory of special creation is mentioned in the conventional religious literature. This theory has three ideas. One, that all living organisms were created as such. Two, that diversity was always the same since creation and will be the same in future also. Three, that earth is about 4000 years old.

These ideas were strongly challenged during the nineteenth century.

Based on observations made during his world tour on a ship H.M.S. Beagle round the world, for five years (1831–1836), **Charles Darwin** concluded that all the existing living

forms share similarities to varying degrees not only among themselves but also with forms that existed millions of years ago. Evolution of new forms occurs due to occurrence of variations and differential reproduction. Individuals who are better fit in an environment leave more progeny than others. Their survival rate is more and hence are selected by nature. He called it **natural selection**. It involves struggle for existence and survival of the fittest that leads to reproductive fitness. Over the period of time it leads to formation of new species.

Alfred Wallace, a naturalist who worked in Malay Archipelago (present Indonesia) had also come to similar conclusions around the same time.

- **Organic evolution** is a process of cumulative change of living populations and in the descendant populations of organisms. In other words. It is "**descent with modification**".
- **Charles Darwin** (1809–1882) emphasized the importance of **nature** in evolution.
- **Hugo de Vries** (1848–1935) stated that **mutations** (sudden change in the genetic material) are responsible for evolution.
- **Aristotle** (384–322 BC) recognized "A ladder-like gradation in nature". He called it **Ladder of Nature** which is also called **Aristotle's Scala Naturae**. This is also known as the **Great Chain of Being**. The Ladder of Nature represents a chain like series of organisms (living beings) leading from the lowest forms up to man, placed at the top. It shows that one higher group evolved from other lower one.

Useful Information About Fossils.

The study of fossils is known as **palaeontology**. **Leonardo da* Vinci** (1452–1519), is called '**The Father of Palaeontology**'. However, modern Palaeontology was established by **Georges Cuvier** (1800) who is, therefore, called "**The Founder of Modern Palaeontology**". *The fossils can be defined as remains or impressions of the hard parts of the past individuals in the strata of the earth.* Fossils provide one of the most acceptable evidences in support of evolution, because we can study the evolutionary past of individuals in the form of their fossils.

Types of Fossils. Five general types of fossils are found.

(i) **Unaltered Fossils (Original Soft Parts of Animals).** In this type, whole bodies of extinct organisms are found frozen in ice at the poles or trapped in amber (fossilized resin of conifers). About 25,000 years old frozen elephant-like **wooly mammoths** were found buried in ice in Siberia in early part of 20th century. Their flesh was so well preserved that it could be fed to dogs.

(ii) **Petrified Fossils (Altered Fossils).** Replacement of organic parts by mineral deposits is called **petrification**. Infact petrification is complete *mineralization* of original structures by which more or less the original material is preserved. Fossils formed through petrification are termed **petrified fossils**. Petrified fossils are as old as 50 crore years and have also been excavated. These fossils consist of only the hard parts (e.g., bones, shells, teeth, wood, etc.) of extinct organisms.

(iii) **Moulds and Casts.** Moulds of hardened and fossilized mud that surrounded an extinct individuals, have been found. In most cases, the buried individuals have been completely destroyed, but the moulds have retained true copies of their shapes. Sometimes, a mould is found with petrified fossil of the individual also. Such fossils are termed **casts**.

(iv) **Prints.** Footprints or prints of leaves, stems, skin, wing, etc. made in soft mud, which subsequently became fossilized, are a common type of fossils.

*da means 'of' in Italian language.

(v) **Coprolites.** Faecal pellets buried in sediments are called **coprolites**. These are usually *phosphatic* in composition.

The fossils of spores, pollen grains and other microscopic structures are called **microfossils** or **palynofossils**.

Determination of the Age of Fossils. The age of the fossils is determined by three methods.

(i) **Uranium– Lead Technique.** This method is based on conversion of unstable radioactive nuclei into stable nuclei over a fixed period. This method was introduced by **Boltwood** in 1907. It has been estimated that one million gram of uranium (U^{238}) produce 17,600 gram of lead (Pb^{206}) in one year. Therefore, by calculating the amount of lead in a rock, one can approximately estimate the age of the rock and thus the age of the fossil present in it can be calculated.

(ii) **Radio-carbon dating Technique.** This method was introduced by an American chemist **Willard F. Libby** in 1950. He was awarded with Nobel Prize in 1960 for Radio-carbon dating technique. This technique can give accurate dates upon a maximum of about 35,000 years past. Radioactive C-14 occurs naturally. It enters food chains and hence it is found in all living things. C-14 decays to form nitrogen-14.

(iii) **Potassium-Argon Method.** It has recently been used to determine the age of **hominid fossils** in East Africa. This method is useful because potassium is a common element found in all sorts of rocks. It disintegrates to form argon-40. Half life of radioactive potassium is 1300 million years.

Microfossils and Fossil Fuel Exploration. Study of fossils helps us to understand and locate coal and hydrocarbons sources. Microfossils (palynofossils) assist us to locate fossil fuels (they include coal, petroleum and natural gases). Deposits of microfossils near sea-shore help us to locate the formation and accumulation of hydrocarbons. The main source of hydrocarbons are phytoplankton, marine and terrestrial algae and also lipid-rich plant remains. Thus the study of fossil plants can be used in obtaining organic fuel resources.

Mass Extinctions. When plants and animals become extinct on a large scale over relatively short span of time, such episodes are called **mass extinctions**. Mass extinctions of dinosaurs took place about sixty million years ago.

Fossil Parks of India. India has a large number of deposits of **fossil plants**. It is thought that they survived about 3,500 million years ago. Twenty million years old fossil forests have been discovered and studied by the **Birbal Sahni Institute of Palaeobotany, Lucknow**. This institute is named after the late **Professor Birbal Sahni** who did extensive palaeobotanical work in India.

Some of fossil forests (fossil parks) of India are given below :

- (i) Fossil Forest in Mandla district, Madhya Pradesh.
 - (ii) Fossil Forest in Rajmahal Hills, Bihar.
 - (iii) Coal-forming fossil forest in Orissa.
 - (iv) National Fossil Park, Tiruvakkarai is found in South-Arcot-District of Tamil Nadu.
- Fossilized trunks of trees are kept in the Children Park, Guindy, Chennai.

The Geological Time Scale. The first geological time scale was developed by **Giovanni Avduina**, Italian scientist in 1760. The age of the earth is about 4600 million years. Life first originated in water about 3600 million years ago. The history of the earth has been divided into a number of major divisions called **eras**. The eras are sub-divided into **periods**. The

modern periods are further divided into **epochs**. By studying fossils occurring in different strata of rocks, geologists are able to reconstruct the time and course of evolutionary change.

Table 7.1. Time Scale of Earth (To be read from below upwards)

Era	Period Age in million years from Present	Epoch Age in million years from present	Fauna (Animals)	Flora (Plants)
Cenozoic (Era of Modern Life) Age of Mammals and Angiosperms	Quaternary 0—2	Recent (Holocene) (0.01)	Modern man dominant; Modern mammals, birds, fishes, insects.	Rise of herbaceous plants, decline of woody plants
		Pleistocene 2	Extinction of great mammals; Evolution of <i>Homo-sapiens</i> and human society and culture	
	Tertiary 2—65	Pliocene 6—7 (Age of Mammals)	Evolution of primitive man like forms from man-like apes.	Adaptive radiation of Flowering plants.
		Miocene 26	Mammals at peak, first man-like apes formed.	
		Oligocene 38	Extinction of archaic mammals. Rise of first monkeys and apes.	
		Eocene 54	Diversification of placental mammals, origin of horse.	Angiosperm dominance increases
		Palaeocene 65	Rise of first primates.	
Mesozoic (Era of Medieval life)	Cretaceous 135		Extinction of dinosaurs & toothed birds; Rise of modern fishes & birds, & of placental mammals.	Dominance of flowering plants.
Palaeozoic (Era of Ancient Life)	Jurassic 145 (Age of Reptiles)		Origin of birds; Dinosaurs dominant.	Origin of flowering plants. Dominance of gymnosperms
	Triassic 225		Origin of dinosaurs and mammals.	Abundance of cycads and conifers.
	Permian 280		Extinction of trilobites. Origin of mammals-like reptile (therapsids) & most modern orders of insects.	Origin of conifers.
	Carboniferous 350 (Age of Amphibians)		Origin of reptiles and winged insects. Amphibians dominant.	Abundance of tree-ferns, forming coal forests.
	Devonian 400 (Age of Fishes)		Origin of amphibians; fishes abundant; spiders appeared.	Earliest mosses and ferns. First seed plants appeared
	Silurian 440		Origin of jawed fishes and wingless insects; earliest coral reefs.	Earliest spore-bearing plants.
	Ordovician 500 (Age of invertebrates)		Origin of vertebrates/ Origin of fishes; invertebrates abundant, also called age of giant molluscs	

	Cambrian 570	All invertebrate phyla established ; origin of trilobites
Proterozoic (Era of Early Life)	1000	Origin of invertebrates First eukaryotes; scanty fossils. Prokaryotes
	2000	
	3000	
Archaeozoic (Era of invisible life)	3500	Origin of prokaryotes; no recognizable fossils
Azoic (Era of no life)	4600	Origin of solar system No life

WHAT ARE THE EVIDENCES FOR EVOLUTION

In support of organic evolution some important evidences are as follows:

1. Palaeontological Evidences (Evidences from Fossil Record)

From the fossil records it has been concluded that evolution has taken place from simple to complex in a gradual manner. In support of it, some evidences are given below.

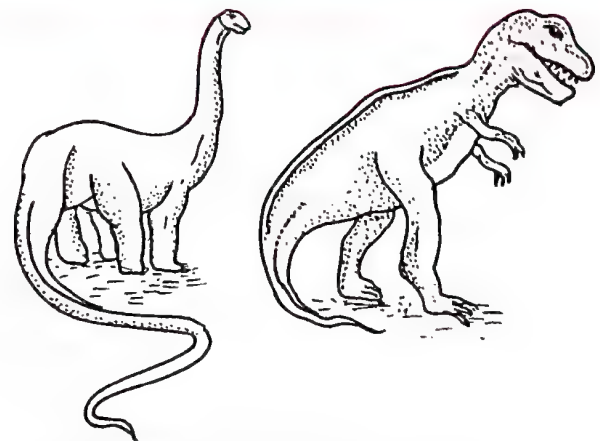
(i) **Number and Nature of Fossils in Early Rocks.** The rocks of early era (e.g., Proterozoic) contain less number of fossils than the rocks of later era and only fossils of simple marine invertebrates are in these rocks. It is due to the fact that the life first originated in sea as a simple form. So fossils were not in plenty in the beginning as they were in later stage.

(ii) **Distribution of Fossils in the Successive Strata.** The rocks of the proterozoic era contain few fossils. The palaeozoic era contains abundant fossils of invertebrates, fishes and amphibians. The rocks of the mesozoic era have the fossils of great reptiles (dinosaurs) and primitive birds and mammals. *Brontosaurus* was herbivore dinosaur, 25 metres long, 4.5 metres high and 45 metric tonnes in weight. *Tyrannosaurus* was the largest of the flesh-eating dinosaurs, 5.4 metres tall and 13 metres long. In the coenozoic era, the fossils of various mammals are abundant.

(iii) **Disparity between the Past and Present Forms of Life.** On the basis of fossil study, it has been shown that the early organisms were very different from their modern forms, viz., the early man lived in the caves without any social life and spent their life like beasts, but man progressed and the modern man has become civilized, and leads a vigorous social life. Thus, the organisms have been changing since their appearance, which supports that evolution has been taking place.

(iv) **Missing Links (Transitional Forms).** The fossil organisms which show characters of two different groups are called missing links.

Examples. (a) *Archaeopteryx* (Archae — primitive, old, *pteryx* = wing). It was found in the rocks of the Jurassic period. *Archaeopteryx lithographica* was discovered in 1861 by



BRONTOSAURUS

TYRANNOSAURUS

Fig. 7.11. Left— Herbivore dinosaur.
Right— Largest flesh eating dinosaur.

Andreas Wagner from the lithographic quarry at Solenhofen, Bavaria, in Germany. This fossil is placed in the British Museum, London. It displays the characters of both the reptiles and birds.

Reptilian Characters of *Archaeopteryx*.

(a) The bones are not pneumatic. (b) The jaws are provided with similar teeth. (c) The hand bears a typical reptilian plan and each finger terminates in a claw. (d) Presence of a weak sternum. (e) Presence of free caudal vertebrae as found in lizards.

Avian Characters of *Archaeopteryx*.

(a) Presence of feathers on the body. (b) The two jaws are modified into a beak. (c) The fore limbs are modified into wings. (d) The hind-limbs are built on the typical avian plan. (e) An intimate fusion of the skull bones as seen in the birds.

From the above facts, it is clear that the birds have been evolved from reptilian ancestors. Thus Huxley is justified in calling 'birds are the glorified reptiles'.

(b) *Ichthyostega*. It is a primitive fossil amphibian and is a missing link between fishes and amphibians.

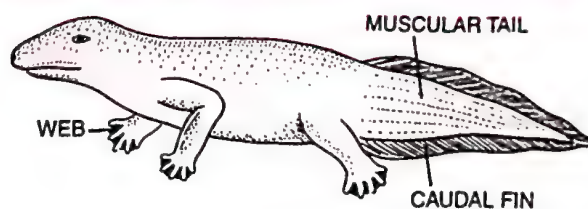


Fig. 7.13. *Ichthyostega*.



Fig. 7.14. *Seymouria*.

(c) *Seymouria*. It was a "missing link" between amphibians and reptiles.

(d) *Lycaenops*. It was a mammal-like reptile. It is considered a "missing link" between reptiles and mammals.



Fig. 7.15. *Lycaenops*.

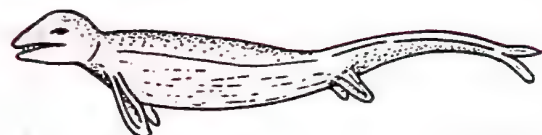


Fig. 7.16. *Basilosaurus* with hind limbs.

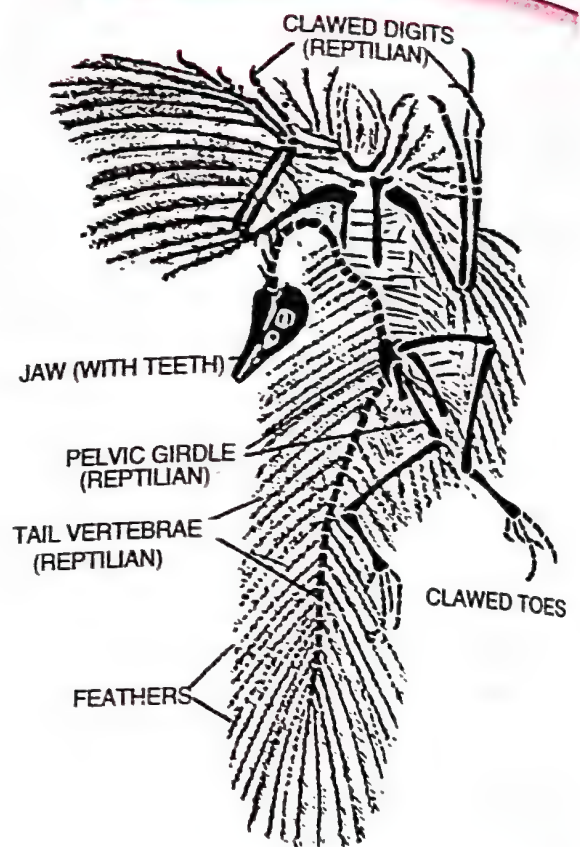


Fig. 7.12. *Archaeopteryx* fossil after restoration.

(e) **Cynognathus** (Dog Jaw). It was a mammal-like reptile and had characters of both reptiles and mammals. It was one of the ancient reptilian ancestors of mammals.

(f) **Basilosaurus**. This fossil whale had hind-limbs. It links the aquatic mammals to their terrestrial ancestors.

(g) **Pteridosperms** (Cycadofilicales, Seed Ferns). These are fossil plants which are intermediate between ferns and seed plants.

There are more animal fossils as compared to plants. It is due to presence of slow decaying harder structures in their endoskeleton and exoskeleton.

(v) **Ancestries of Some Animals**. Palaeontologists have traced out complete evolutionary histories of some animals like horse, camel and elephant and man from the studies of their fossils.

Evolution of Horse. Evolution of horse was described by **Othniel C. Marsh** in 1879. **Place of Origin**— Origin of horse took place in **Eocene epoch**. *The first fossil of the horse was found in North America. It was named Eohippus, but later renamed Hyracotherium.*

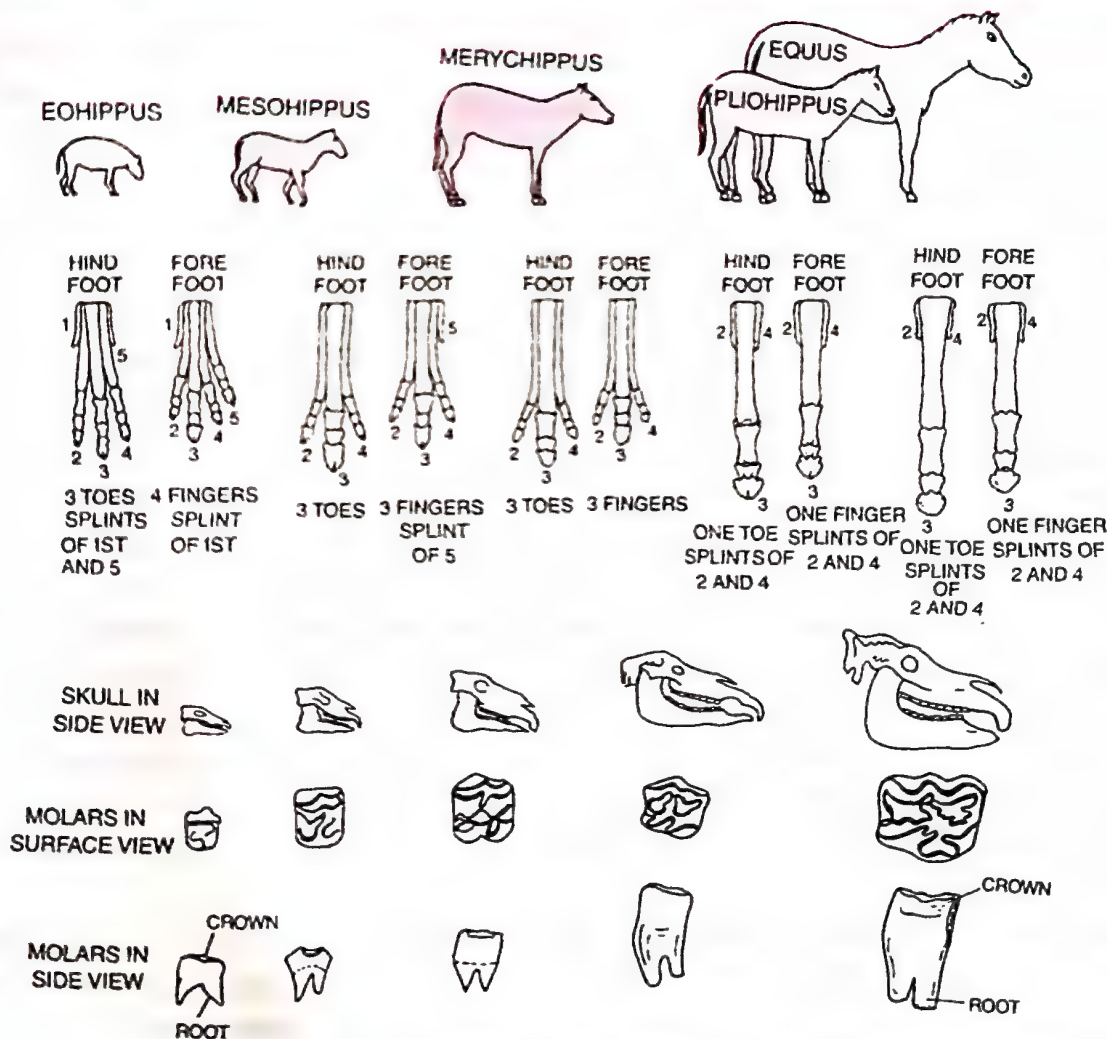


Fig. 7.17. Diagrams illustrating the evolution of the horse. *Top row.* Progressive change in size. *Second row.* Bones of hind and fore feet showing reduction in lateral toes and fingers. *Third row.* Skulls showing changes in size and outline. *Fourth row.* Molar showing increasing complexity of enamel pattern (black). *Fifth row.* Molar showing increase in size.

Evolutionary Trend. The continuous change of a character within an evolving lineage is called **evolutionary trend**. A lineage is an evolutionary sequence, arranged in linear order

from an ancestral group to a descendant group. A trend may be progressive (a general increase in size of organs) or retrogressive (a general degeneration and loss of organs). The following list identifies the major evolutionary trend of horses.

(a) Increase in size. (b) Elongation of neck and head. (c) Lengthening of fore and hind limbs. (d) Reduction of lateral digits. (e) Increase in length and thickness of the third digit. (f) Straight-ening and stiffening of the back. (g) Increase in size and complexity of the brain. (h) Better developed sense organs. (i) Increase in tooth length. (j) Increase in width of incisors. (k) Replacement of premolars by molars. (l) Increase in crown height of molars. (m) Increased lateral support of teeth by cement. (n) Increased surface area of cusps by the development of enamel ridges (change in premolars and molars teeth from browsing type to grazing type).

Evolution of Modern Horse is briefly described as follows :

Eohippus (= **Hyracotherium**). The evolution of modern horse began about 60 million years ago in the **Eocene epoch**. As stated earlier first fossil named *Eohippus*, 'dawn horse', was found in North America. This horse was about the size of a fox or terrier dog (a type of small haired dog for unearthing foxes), only 30 cm high at the shoulders. It had short head and neck. The fore feet were with four complete fingers (2, 3, 4 and 5) and one splint of first finger and the hind feet with three functional toes (2, 3 and 4) and two splints of first and fifth toes. Splints are reduced and nonfunctional side fingers and toes of horse. Teeth were within complete cement. Molar teeth had no serrations. Low-crowned molar teeth were adapted to browsing of soft lush vegetation.

Mesohippus. *Mesohippus*, the intermediate horse, evolved from *Hyracotherium* about 40 million years ago during **Oligocene epoch**. It was of the size of modern sheep, about 60 cm high at the shoulders. Fore feet had three fingers and one splint of fifth finger and hind feet possessed three toes, but the middle one was longer than others and supported most of the body weight. Molar teeth had some serrations.

Merychippus. *Merychippus*, the ruminating horse, arose from *Mesohippus* in Miocene epoch about 25 million years ago. It was of the size of small pony, about 100 cm high at the shoulders. It was with longer neck. Its fore and hind feet had three fingers and three toes, the middle finger and toe being longer than others and supported entire body weight. There was no splint. Teeth were longer with cement. Molar teeth had well developed serrations.

Pliohippus. *Pliohippus*, the **Pliocene horse**, evolved from *Merychippus* in **Pliocene epoch** about 10 million years ago. It was the size of modern pony, about 120 cm high at the shoulders. Its each fore and hind foot had one complete finger and one complete toe and two splints hidden beneath the skin. *Pliohippus* is, therefore, referred to be the first one toed horse. The molar teeth were long with well developed cement and serrations. Teeth were adapted for eating grass.

Equus. This is the modern horse which arose from *Pliohippus* in **Pleistocene epoch** about nine to ten lakh years ago in North America and later spread throughout the world except Australia. It is about 150 cm high at the shoulders. It has a long head and a long neck. Each fore and hind foot of the modern horse has one finger and one toe and two splints. The crowns of molar teeth are elongated with enameled ridges, and are highly suitable for grinding.

2. Evidences from Comparative Anatomy and Morphology

There are similarities and differences among organisms of today and those existed years ago. These evidences are as follows.

(i) **Organ Systems.** The different systems of animal body are similar in many groups of organisms, e.g., nervous system, blood vascular system, respiratory system, excretory system, etc.

(ii) **Homologous organs.** Richard Owen (1804–1892) introduced the term **homologous**. The organs which have the same fundamental structure but are different in functions are called **homologous organs**. These organs follow the same basic plan of organisation during their development. But in the adult condition, these organs are modified to perform different functions as an adaptation to different environments. The homologous structures are a result of **divergent evolution**. Homology indicates common ancestry.

Examples : (a) The *fore-limbs of man, cheetah, whale and bat* have the same basic structural plan. But the fore-limbs of these animals have different shapes and functions. In man they are used for grasping, in cheetah for running, in whale for swimming and in bat for flying (Fig. 7.19).

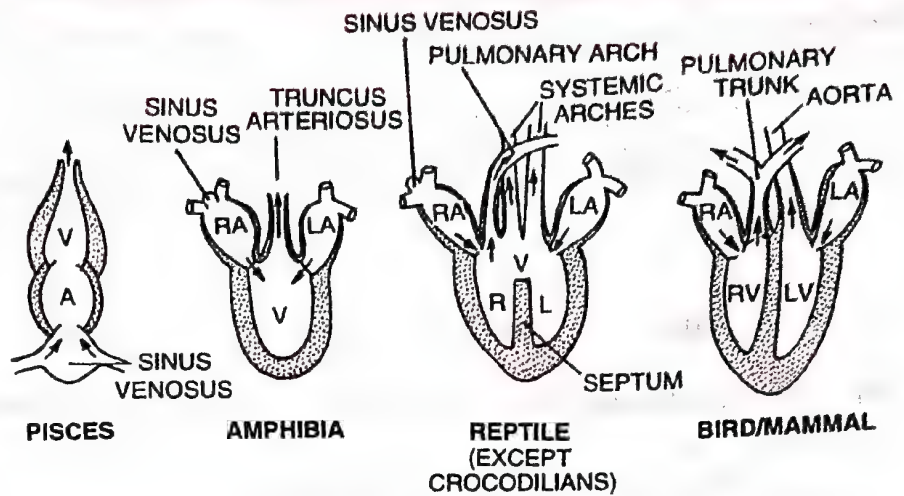


Fig. 7.18. Hearts of different vertebrates Note the progressive complexity. A = Auricle, V = Ventricle, R = Right, L = Left.

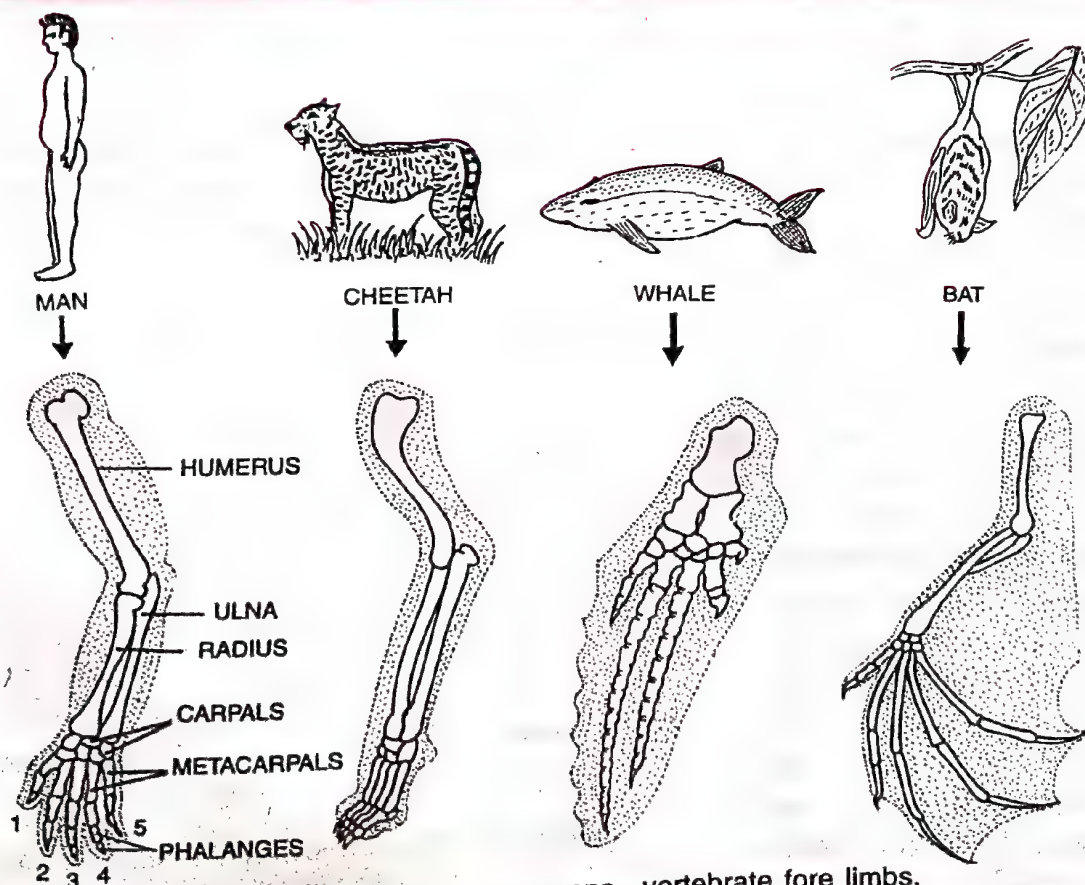


Fig. 7.19. Homologous organs—vertebrate fore limbs.

(b) *Structural homology* is also seen in the skeleton, heart, blood vessels, brain, nerves, muscles and excretory system of different vertebrates.

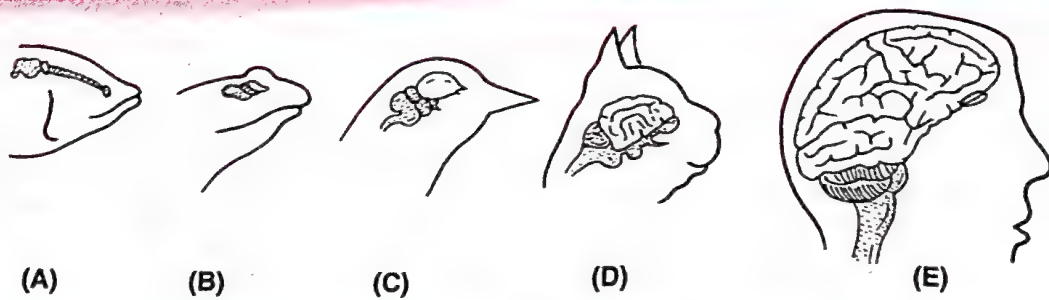


Fig. 7.20. Homologous structures: vertebrate brain (a) fish, (b) frog, (c) bird, (d) cat and (e) human being.

(c) Another example of homologous organs is of different **mouth parts of some insects**. The mouth parts of cockroach, honey bee, mosquito and butterfly have the same fundamental plan, but they have different functions to perform, keeping in view their different feeding habits. The mouth parts in cockroach are adapted for biting and chewing. In honey-bee for chewing and lapping, in mosquito for piercing and sucking, in housefly for sponging and in butterfly for siphoning.

(d) In plants, the homologous organs may be a thorn of *Bougainvillea* or a tendril of *Curcubita*, both arising in the axillary position.

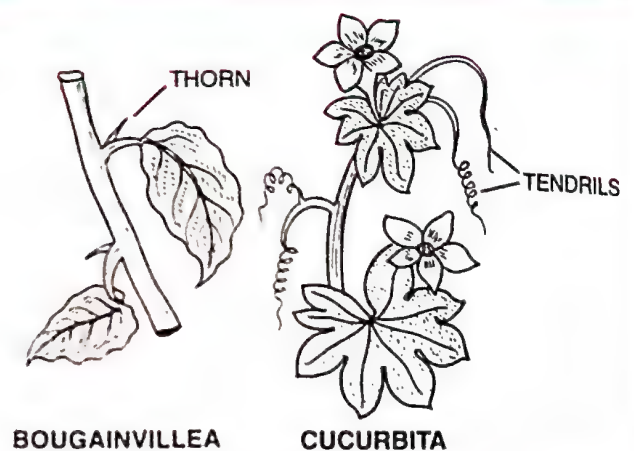


Fig. 7.21. Homologous structures. Thorns and tendrils in plants.

(e) Homology is also seen amongst the molecules. This is called **molecular homology**. For example, the proteins found in the blood of man and ape are similar. The phylogeny of an organism can be traced by using the base sequence in nucleic acids and amino acid sequence of proteins in related organisms.

(iii) Analogous Organs.

The organs which have similar functions but are different in their structural details and origin are called analogous organs. The analogous structures are the result of **convergent evolution**.

Examples : (a) The wings of an insect are analogous to wings of a bird. It is due to the fact that the basic structure of the wings of the insects is different from the wings of bird. However, their function is similar (Fig. 7.22).

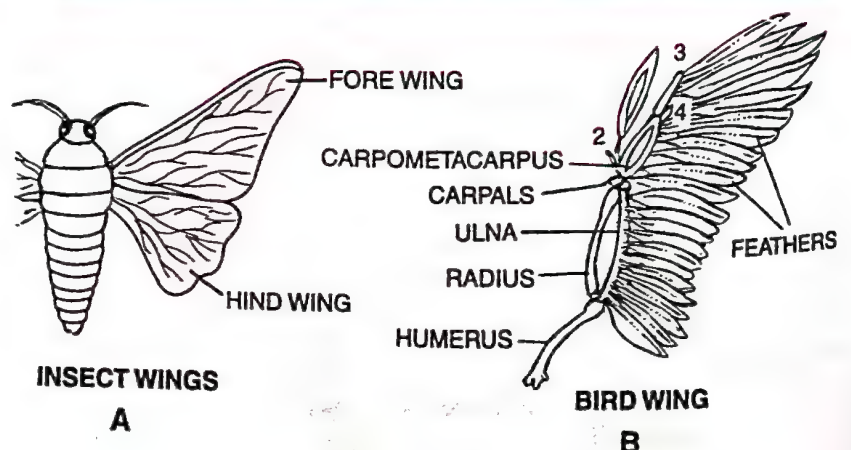


Fig. 7.22. The wings of an insect are analogous to wings of bird.

- (b) Pectoral Fins of sharks and flippers of Dolphins are analogous organs.
 (c) Stings of honey bee and scorpion are analogous structures.

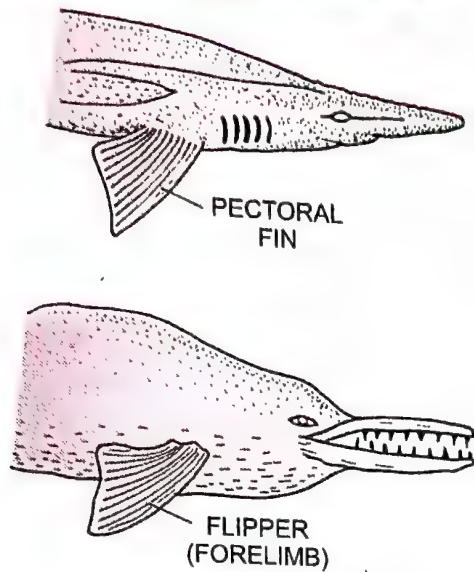


Fig. 7.23. Pectoral fin of shark and flipper of Dolphin.

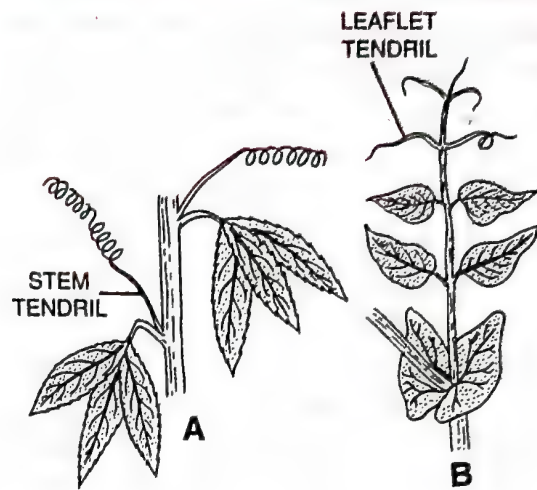


Fig. 7.24. Analogous Organs. Tendrils of different origin. A, stem tendrils of *Passiflora* B, leaf tendrils of *Pisum sativum*.

(d) Eye of octopus and eye of cat show different patterns of structure, yet they perform similar function. This is an example of analogous organs.

(e) Plant tendrils are meant for climbing. They can be derived from stem branches (e.g., *Passiflora*), leaves (e.g., *Lathyrus aphaca*, *Pisum sativum*). The presence of analogous organs indicate a similar adaptation by unrelated groups through modification or evolution of different parts. It is called *convergent evolution*.

Differences Between Homologous and Analogous Organs

Homologous Organs	Analogous Organs
<ol style="list-style-type: none"> 1. They differ morphologically. 2. They have similar internal structure. 3. They develop in related organisms. 4. Stages in the development are similar. 5. They perform different functions. 6. They have similar developmental pattern. 7. Homologous organs show adaptive radiation (divergent evolution). 	<ol style="list-style-type: none"> 1. They show superficial resemblance. 2. Their internal structure is quite different. 3. They develop in unrelated organisms. 4. Stages in the development are different. 5. They have similar functions. 6. They have dissimilar developmental pattern. 7. Analogous organs show convergent evolution.

(iv) **Vestigial Organs.** The organs which are present in reduced form and do not perform any function in the body but correspond to the fully developed functional organs of related animals are called **vestigial organs**. They are believed to be remnants of organs which were complete and functional in their ancestors.

Examples : (a) Vestigial Organs in Human Body. Human body has been described to possess about 90 vestigial organs. Some of these are nictitating (plica semilunaris) membrane, auricular muscles, (muscles of pinna), segmental muscles of abdomen, panniculus carnosus (subcutaneous muscles), vermiform appendix, caudal vertebrae (also called coccyx or tail bone), third molars (wisdom teeth), hair on body, and nipples in male (Fig. 7.25).

(b) Vestigial Organs in Animals. Important examples are vestiges of hindlimbs and pelvic girdles of pythons (Fig. 7.26) and greenland whales, (which show that snakes and whales originally evolved from four-footed ancestors), wings of flightless birds such as Ostrich; Emu, Cassowary, Kiwi, Rhea and Dodo (extinct) and splint bones in feet of horse.

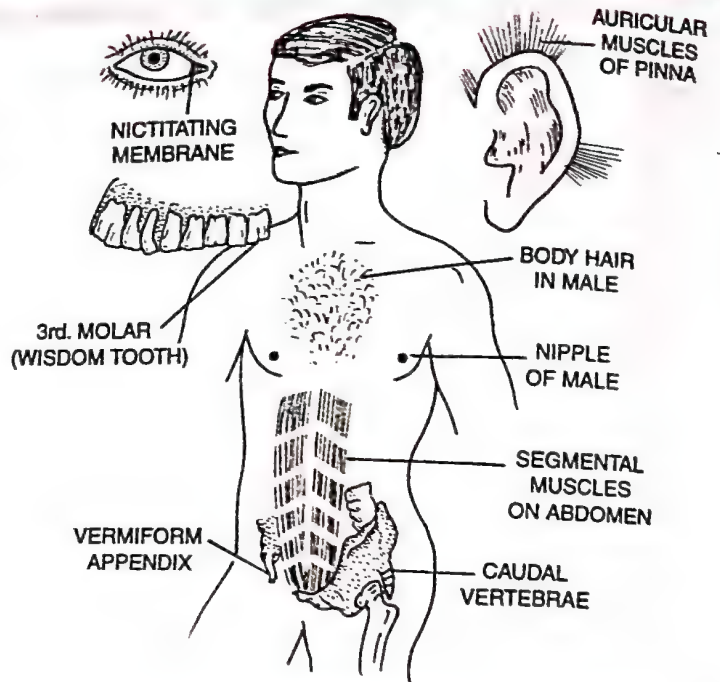


Fig. 7.25. Some vestigial organs in human body.

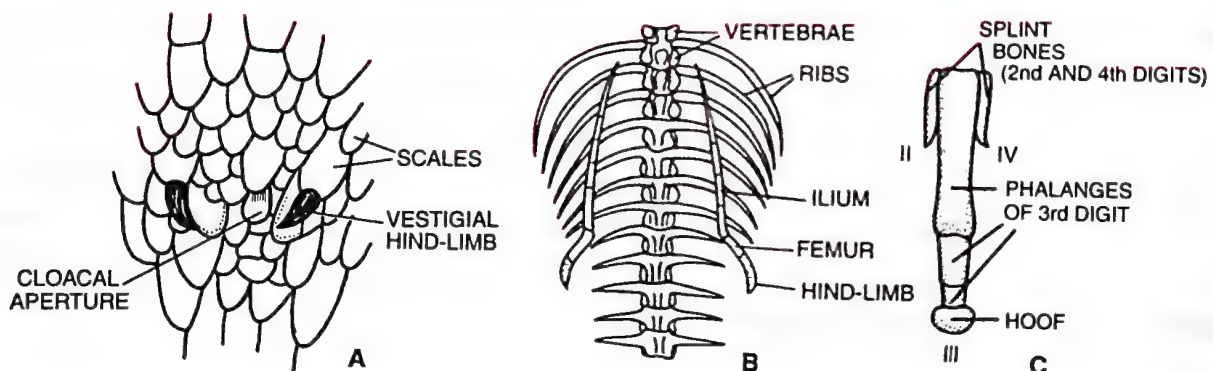


Fig. 7.26. A, External view of vestigial hind limbs of python; B, vestigial pelvic girdles and bones of the hind limbs in python; C, Splint bones in hind limb of modern horse.

(c) Vestigial Organs in Plants. Leaves are reduced to scales in *Cuscuta*, *Orobancha*, *Asparagus*, *Ruscus* and a number of other plants.

(v) Connecting Links. The organisms which possess the characters of two different groups are called **connecting links**. Following are some important examples of connecting links.

Examples : (a) Euglena is a connecting link between the animals and plants.

(b) Proterospongia is a link between Protozoa and Porifera.

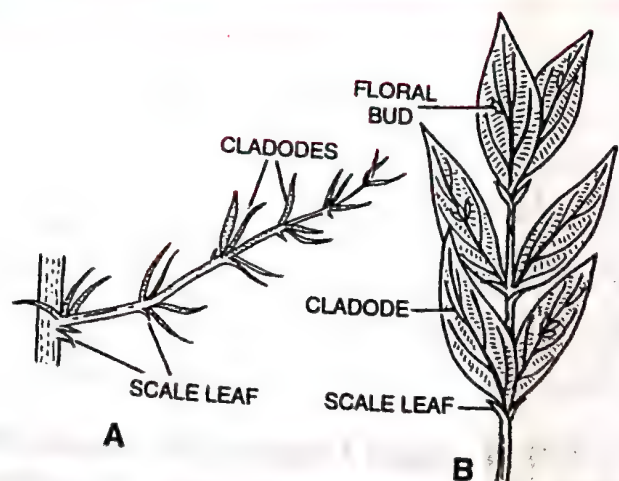


Fig. 7.27. Vestigial or scale leaves. A, *Asparagus*; B, *Ruscus*.

(c) *Neopalina* is a connecting link between Annelida and Mollusca.

(d) *Peripatus*, an arthropod, is a connecting link between annelida and arthropoda.

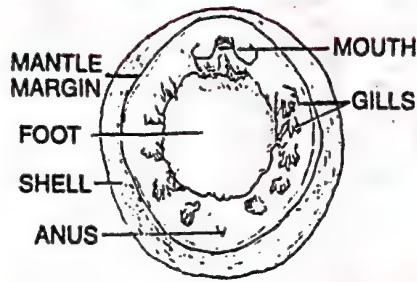


Fig. 7.28. *Neopalina*.



Fig. 7.29. *Peripatus*.

(e) *Balanoglossus*. It is a hemichordate (nonchordate) and is a connecting link between nonchordates and chordates.

(f) The **lung fishes** may be considered the connecting links between the fishes and amphibians.

(g) *Latimeria* (Coelocanth fish) is considered a connecting link between fish and amphibians.

(h) *Chimaera*. It is a connecting link between cartilaginous fishes and bony fishes.

(i) **Egg-laying mammals** (e.g., *Ornithorhynchus*, Duck-billed platypus and *Tachyglossus* or *Echidna* or Spiny ant eater) are connecting link between reptiles and mammals.

(j) *Sphenodon*. It is a connecting link between amphibians and reptiles.

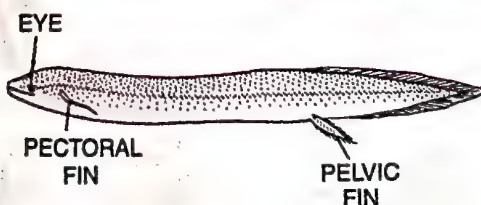


Fig. 7.30. *Protopterus* (African Lung-fish).

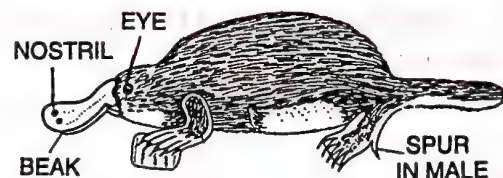


Fig. 7.31. Duck-billed platypus.

Differences Between Connecting and Missing Links

Connecting Links	Missing Links
1. The living organisms which have the characters of two different groups are called connecting links.	1. The fossil organisms which show characters of two different groups are called missing links.
2. They are living organisms.	2. They are fossil organisms.
3. Examples : <i>Peripatus</i> , <i>Neopilina</i> , <i>Protopterus</i> , <i>Ornithorhynchus</i> , etc.	3. Examples : <i>Ichthyostega</i> , <i>Seymouria</i> , <i>Cynognathus</i> , <i>Basilosaurus</i> , etc.

(vi) **Atavism**. It is the reappearance of certain ancestral characters which had either disappeared or were reduced. There are present some examples of atavism in human beings,

viz., the power of moving pinna in some persons, greatly developed canine teeth, exceptionally long dense hairs, short tail in some babies (Fig. 7.32) and presence of additional mammae in some individuals.

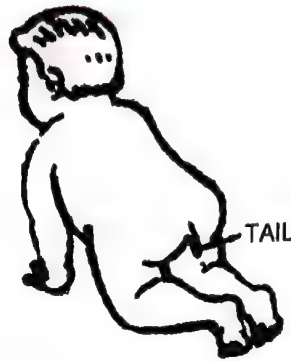


Fig. 7.32. Tail in human child.

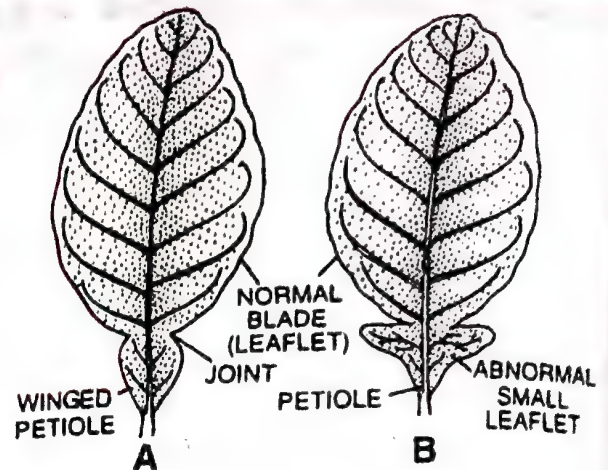


Fig. 7.33. Atavism. A, normal *Citrus* leaf showing joint winged petiole; B, an abnormal leaf with two additional leaflets (atavism).

Citrus leaf was once trifoliolate compound but during evolution two leaflets have degenerated (Fig. 7.33). In many plants (e.g., *Rosa*, *Hibiscus*, *Oxalis*, *Poppy*), some of the stamens and even carpels get changed to petal-like structures indicating that stamens and carpels have evolved from leaf-like structures.

3. Embryological Evidences (Evidences from Embryology)

These evidences are based on the comparative study of the embryos of various animals.

(i) **Similarity in Early Development.** In all the multicellular animals the fertilized egg (zygote) undergoes segmentation (cleavage) to produce a solid structure, the **morula**. The morula develops into a single layered hollow **blastula**. The latter changes into either two or three layered **gastrula**. The animals having two layered gastrula are said to be **diploblastic**, e.g., coelenterates. The animals in which three layered gastrula is found are known as **triploblastic**, such as frog, lizard, etc. Diploblastic gastrula consists of ectoderm and endoderm. These two or three layers of gastrula are termed as **primary germ layers**, which give rise to the entire animal. Such a similar early development establishes a close relationship among all multicellular animals.

(ii) **Resemblance among Vertebrate Embryos.** If a comparative study of embryos

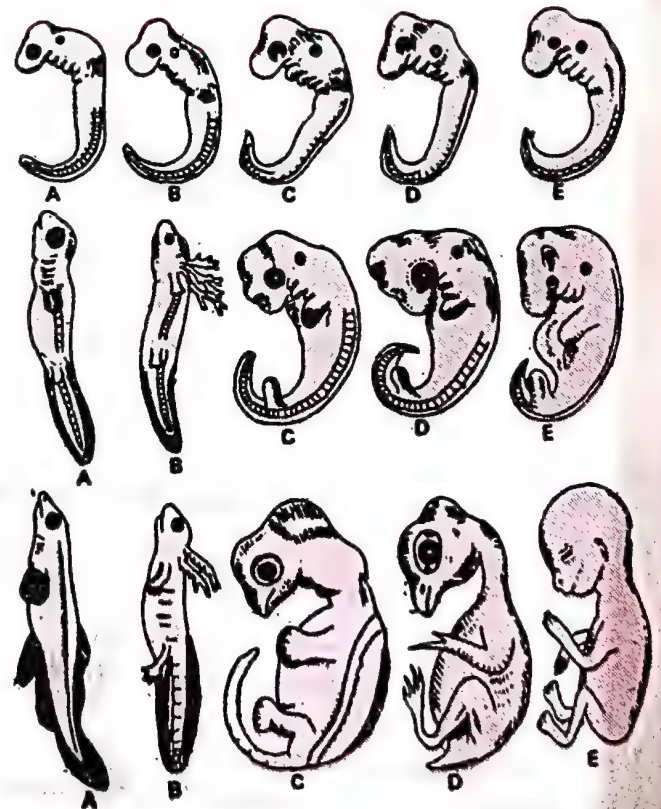


Fig. 7.34. Vertebrate embryos in three successive and comparable stages of development. A, Fish; B, Salamander; C, Tortoise; D, Chick; E, Man.

of the same age of vertebrates, such as a fish, a salamander, a tortoise, a chick and a man is made, it is observed that they resemble one another closely (Fig. 7.34).

(iii) **Resemblances among Invertebrate Larvae.** Annelids and molluscs possess a similar type of larva called trochophore. Echinoderms and hemichordates also have similar larvae. Larval resemblance points to a common ancestry.

(iv) **Progressive Metamorphosis.** Ammocoete larva of Lamprey resembles the adult form of *Amphioxus* or *Branchiostoma* in most of the details which are possible only if we presume that Lamprey has evolved from *Branchiostoma* like animals.

(v) **Retrogressive Metamorphosis.** Animals like *Sacculina* and tunicates (e.g., *Herdmania*) are degenerates and do not show any resemblance to other groups of animals. However, the study of their embryology has helped as to find their true systematic position on account of the characters present in their embryos.

(vi) **Temporary Embryonic Structures.** Embryos often possess structures which do not occur in the adults. For example, bird embryo has tooth buds and gill clefts which are not found in the adult animal.

Early tadpole of frog possesses gills and tail, during metamorphosis these structures disappear.

(vii) **Development of Vertebrate Organs.** Development of many vertebrate organs (e.g., heart, brain, kidney) indicate the possible path of evolution as well as the common ancestry of vertebrates.

(viii) **Evidences from Plant Embryos.** (a) In *Pinus* the foliage leaves do not occur directly on the main stems but are borne in clusters on the dwarf shoots. However, in the seedling state the foliage leaves occur directly on the main stem indicating evolution of *Pinus* from ancestors that possessed foliage leaves directly on main stems. (b) Australian species of *Acacia* possess phyllodes (Fig. 7.35) or foliaceous petioles instead of normal bipinnate leaves as in other species of *Acacia*. Australian species show all the transitional steps between bipinnate leaves and phyllodes during the seedling stage. (c) Many bryophytes pass through a filamentous protonema stage before attaining adult form. The filamentous protonema suggests algal ancestry for bryophytes. (d) Bryophytes and pteridophytes have ciliated male gametes or sperms. They require an external source of water for swimming to the female sex organs. In gymnosperms the sperms are transported by pollen tubes. Even then sperms of cycas and *Ginkgo* are ciliated.

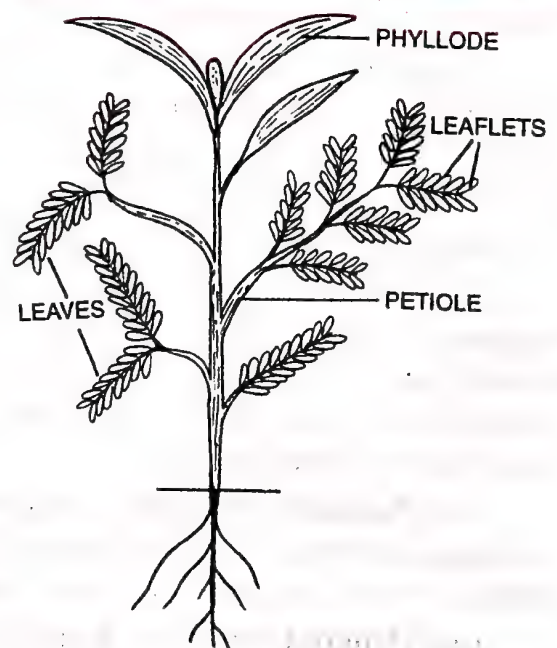


Fig. 7.35. Australian *Acacia* showing transition from bipinnate leaves to phyllodes in a seedling.

(ix) **Recapitulation Theory/Biogenetic Law.** In 1828, Von Baer, the father of modern embryology, proposed Baer's law which stated that during embryonic development, the generalised features (such as brain, spinal cord, axial skeleton, aortic arches, etc. are common to all vertebrates) appeared earlier than the special features (like hair in mammals only, features in birds only, limbs found in quadrupeds only) which distinguish the various members of the group. Later on this law was modified as the biogenetic law by Ernst Haeckel

in 1866. Haeckel's biogenetic law states that "**Ontogeny repeats phylogeny**". Ontogeny is the life history of an organism while phylogeny is the evolutionary history of the race of that organism. In other words an organism repeats its ancestral history during its development.

Examples: (a) In the development of the frog a fish like tailed larva (**tadpole**) is formed, which swims with the tail and respire by the gills. This indicates that the frog has been evolved from a fish like ancestor.

(b) **Tadpole** (larva) of *Herdmania* (urochordate) shows characters of chordates i.e., presence of notochord, well developed dorsally placed central nervous system and tail. However adult *Herdmania* does not have notochord and tail. Nervous system is also very much reduced in adult *Herdmania*. Thus the larva shows its ancestral characters.

(c) The **protonema**, an early stage in the development of a moss and a fern gametocyte resembles the filamentous green algae in structure, growth pattern and physiology. This indicates an algal ancestry of the bryophytes and pteridophytes.

(d) The gymnosperms have normally become independent of water in fertilization. But the primitive gymnosperms (e.g., *Cycas* and *Ginkgo*) have flagellated sperms and need water for fertilization like the pteridophytes. This indicates that the gymnosperms have descended from the pteridophyte-like ancestor.

4. Biogeographical Evidences (Evidences from Biogeography)

Biogeography is the study of distribution of animals and plants on this earth. The evidences of evolution based on biogeography (*G. bios*— life, *ge*— earth, *grapho*— to write) are called biogeographical evidences.

Pangaea (Gr. all earth). It is believed that around the carboniferous period (about 345 million years ago) or slightly earlier, all the present-day continents were in the form of a single big land mass called **pangaea** (Fig. 7.39). Later on, due to various geological changes, huge land masses broke off and drifted apart from one another.

Biogeographical evidences may be explained under the following headings.

1. Biogeographical Realms. The earth has been divided into six major **biogeographic regions**, called **realms** on the basis of distribution of animals and plants. **Dr. P.L. Sclater** in the year 1858 proposed first time the division of the world into six **realms** or regions according to the distribution of birds. In 1876 **A.R. Wallace** adopted it for all the animals. These realms (regions) are :

(i) **Palaearctic realm.** It includes Europe, north of Himalaya, China, Sahara desert of Africa, Siberia and a major part of Asia. Important Animals : *Anabas*, *Bufo*, *Rhacophorus*, *Alytes*, *Proteus*, *Necturus*, *Varanus*, Alligator, Hawks, Camel, Tiger, Seal, Panda.

(ii) **Oriental realm** — It includes India, Malaysia, Philippines, Indonesia, Sri Lanka, Myanmar (Burma). Important Animals : Carps, Cat fishes, Apods, Frogs, Draco, Python, Cobra, King cobra, Crocodile, *Gavialis*, Peacock, Hornbills, Porcupines, *Loris*, Gibbon, *Rhinoceros*, Elephants, Tiger, Lion.

(iii) **Australian realm.** It covers Australia, New Zealand, New Guinea. Important Animals : *Ceratodus* (Australian Lungfish), *Sphenodon*, *Casuarius*, Emu, Kiwi, Duck billed platypus, Spiny anteater, Opposum, Kangaroo, Marsupial cat.

(iv) **Ethiopian realm.** It includes Africa, Arabia and Madagascar. Important Animals: *Protopterus* (African Lungfish), *Rhacophorus*, Crocodile, Chamaeleon, Python, Ostrich, Scaly-anteater, Chimpanzee, Gorilla, Zebra, Elephants, *Hippopotamus*, *Rhinoceros*, Giraffe, Lion, Tiger.

(v) **Nearctic realm.** It covers Canada, United States of America and Mexico. Important Animals : Sucker fish, Tiger salamander, *Amphiuma*, *Heloderma* (Poisonous Lizard), Alligator, Hawk, Opossum, Porcupine.

(vi) **Neotropical realm.** It includes the area of Central and South America and Island of West-Indies. Important Animals : *Lepidosiren* (South American Lung fish), Caecilians (Apoda), *Hyla*, *Pipa*, Rattle snake, *Rhea*, Opossum, Vampire bat, Llama (Like Camel), Marsupial rat.

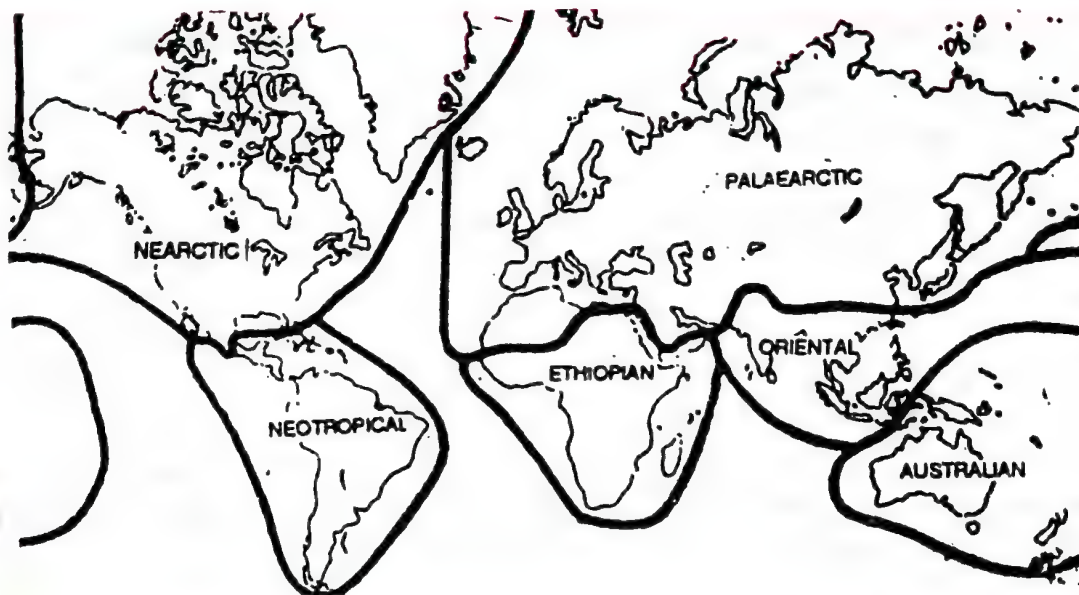


Fig. 7.36. Different biogeographic realms (regions) of the world.

Oriental realm is separated from Palearctic realm by Himalayan mountains. Ethiopian realm and Australian realm are separated by sea (Fig. 7.36).

Oriental realm and Australian realm are separated by **Wallace's line** (Fig. 7.66).

Palearctic realm and Nearctic realm together form **Holoarctic region**.

2. Discontinuous Distribution of closely related species. Sometimes closely similar species exist at widely separated places without any representative in intervening territory. This is called **discontinuous distribution**. Two specific examples of discontinuous distribution are given below.

(a) **Alligators.** They occur only in south-eastern United States and eastern China.

(b) **Lung Fishes.** Now the lung fishes are only found in South America, Africa and Australia as shown in the (Fig. 7.37).

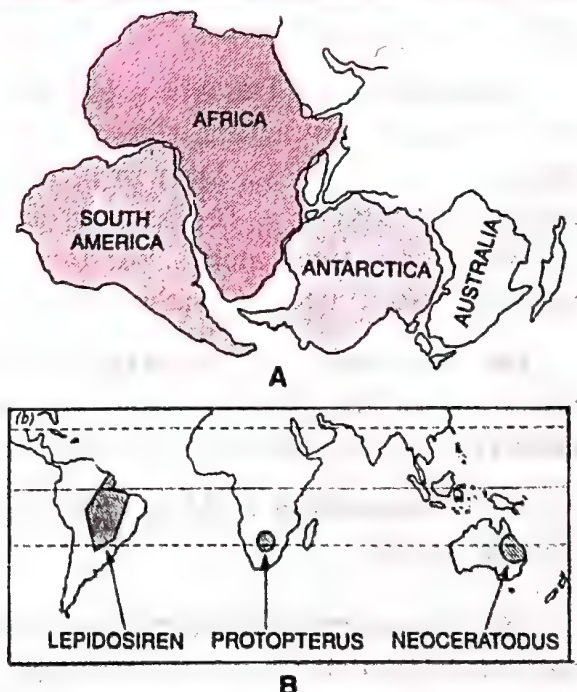


Fig. 7.37. (A) Figure showing relative positions of South America, Africa, Antarctica and Australia during early stages of continental drift indicating the areas where lung fishes may have originated. (B) Present distribution of lung fishes.

If we look at a map of the world on a sheet of paper, cut out the outlines of South America and Africa and bring them together. We find that the right side of South America fits into the left side of Africa.

(c) **Camels.** They occur in Asia, while their nearest allies Llamas are found in South America.

(d) **Elephants.** They are found in Africa and India and not in places with identical climate in Brazil.

(e) **Tapirs.** They are found in tropical America and Malayan islands.

(f) **Magnolias¹, Tulips² and Sassafras³.** These plants now grow naturally in the eastern USA and in China only. The reason is the same as for the alligators.

3. Restricted Distribution. The parts separated from the main land have unique fauna and flora. For example, Australia has (i) **egg-laying** and (ii) **pouched mammals** that occur only in Australia. This restricted distribution may be explained in the following way. Australia separated from the main land of Asia during mesozoic era, before placental mammals evolved. Placental mammals, being more adapted, eliminated the egg laying and most of the pouched mammals in other parts of the world. The egg laying and pouched mammals of Australia survived as placental mammals could not reach there due to lack of land route. (iii) Deserts of America possess cacti while those of Africa have euphorbias. (iv) Double coconut is restricted to Seychles island.

4. Adaptive Radiation (= Divergent Evolution). Development of different functional structures from a common ancestral form is called adaptive radiation. The concept of adaptive radiation in evolution was developed by H.F. Osborn in 1902. Homologous organs show adaptive radiation.

Examples. (i) **Darwin's Finches of the Galapagos Islands.** They had common ancestors but now have different types of modified beaks according to their food habits as shown in figure 7.42. Darwin differentiated thirteen species of finches and grouped them into six main types — (a) Large ground finches. (b) Cactus ground finches feeding on cacti. (c) Vegetarian tree finches. (d) Insectivorous tree finches. (e) Warbler* finches. (f) Tool-using or Wood pecker finches. Ancestral finches were seed eating.

(ii) **Australian Marsupials** (Fig. 7.38). Darwin explained that adaptive radiation gave rise to a variety of marsupials (pouched mammals) in Australia in the same process of adaptive radiation as found in the finches in the Galapagos Islands.

(iii) **Locomotion in Mammals.** Adaptive radiation based on locomotion in mammals is good example.

5. Convergent Evolution (= Adaptive Convergence). Development of similar adaptive functional structures in unrelated groups of organisms is called adaptive convergence or convergent evolution.

1. Ornamental flowering shrub or tree with large fragrant flowers. 2. Hardy bulbous herbs with ornamental flowers. 3. Aromatic deciduous tree.

*Warbler — a bird that can make musical sounds.

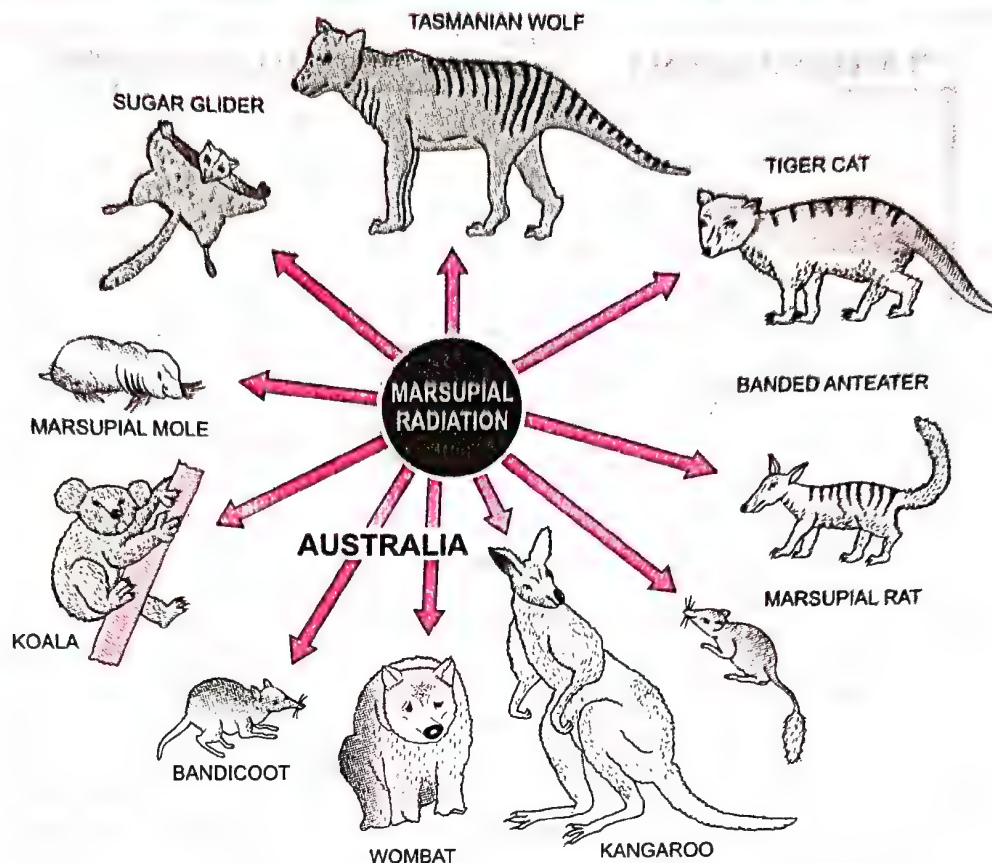


Fig. 7.38. Adaptive radiation of Australian Marsupials.

Examples. (i) wings of insect, bird and bat show marked convergent evolution.

(ii) Australian marsupials and placental mammals show convergent evolution, e.g., Placental wolf and Tasmanian wolf-marsupial (Fig. 7.39).

(iii) Various aquatic vertebrates, not closely related show a marked convergent evolution.

(iv) Anteaters such as spiny anteaters and scaly anteaters belong to different orders of class mammalia, not closely related but have acquired similar adaptations for diet of ants, termites and other insects.

Parallel Evolution. When convergent evolution is found in closely related species, it is called “Parallel Evolution”. **Example :** development of running habit in deer (2-toed) and horse (1-toed) with two vestigial splint bones. Tasmanian wolf is a marsupial while wolf is a placental mammal. This also shows parallelism.

Differences Between Divergent Evolution and Convergent Evolution

Divergent Evolution	Convergent Evolution
<ol style="list-style-type: none"> Development of different functional structures from a common ancestral form is called divergent evolution. Homologous organs show divergent evolution. Examples : Darwin's Finches, Australian Marsupials, locomotion in mammals. 	<ol style="list-style-type: none"> Development of similar adaptive functional structures in unrelated groups of organisms is called convergent evolution. Analogous organs show convergent evolution. Examples : Australian Marsupials and Placental mammals, various aquatic vertebrate and wings of insect, bird and bat.








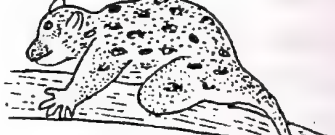





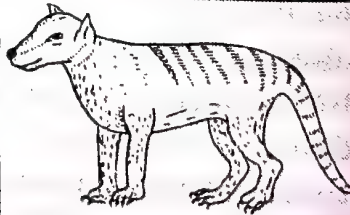
PLACENTAL MAMMALS	HABIT OR ADAPTATION	AUSTRALIAN MARSUPIALS
 MOLE	Burrowing	 MARSUPIAL MOLE
 ANTEATER	Digging Ant Feeder	 NUMBAT (ANTEATER)
 MOUSE	Small Rodent Like	 MARSUPIAL MOUSE
 LEMUR	Arboreal	 SPOTTED CUSCUS
 FLYING SQUIRREL	Arboreal Gliders	 FLYING PHALANGER
 BOBCAT	Cat-Like Carnivore	 TASMANIAN TIGER CAT
 WOLF	Dog-Like Carnivore	 TASMANIAN WOLF

Fig. 7.39. Showing Convergent evolution of Australian marsupials and placental mammals.

THEORIES OF EVOLUTION

- Four theories have been put forward to explain the mode of evolution, *i.e.*, origin of species.
1. Lamarckism or Lamarck's theory of the inheritance of acquired characters.
 2. Darwinism or Darwin's theory of natural selection.
 3. Hugo de Vries' mutation theory
 4. Modern concept of evolution/Synthetic Theory of evolution.

Lamarckism

Lamarckism is the first theory of evolution, which was proposed by **Jean Baptiste de Lamarck** (1744–1829), a French biologist. Although the outline of the theory was brought to notice in 1801, but his famous book "**Philosophic Zoologique**" was published in 1809, in which he discussed his theory in detail. Lamarck coined the terms "**invertebrates**" and "**Annelida**". The term "**Biology**" was given by Lamarck and Treviranus (1802).



Jean Baptiste de Lamarck.

Lamarck's Propositions. Lamarckism includes four main propositions.

(i) **Internal Vital Force.** All the living things and their component parts are continually increased due to internal vital force.

(ii) **Effect of Environment and New Needs.** Environment influences all types of organisms. A change in environment brings about changes in organisms. It gives rise to new needs. New needs or desires produce new structures and change habits of the organisms. Doctrine of desires is called **appetency**.

(iii) **Use and Disuse of Organs.** If an organ is constantly used it would be better developed whereas disuse of organ results in its degeneration.

(iv) **Inheritance of Acquired Characters.** Whatever an individual acquires (to possess) characters in its life time due to internal vital force, effect of environment, new needs and use and disuse of organs, they are inherited (transmitted) to the next generations. The process continues. After several generations, the variations are accumulated upto such extent that they give rise to new species.

Examples in Support of Lamarckism. Lamarck explained his theory by giving the following examples.

(i) **Evolution of Giraffe.** The ancestors of giraffe were bearing a small neck and fore-limbs and were like horses. But as they were living in places with no surface vegetation, they had to stretch their neck and fore-limbs to take the leaves for food, which resulted in the slight elongation of these parts. Whatever they acquired in one generation was transmitted to the next generation with the result that a race of long necked and long fore-limbed animals was developed.

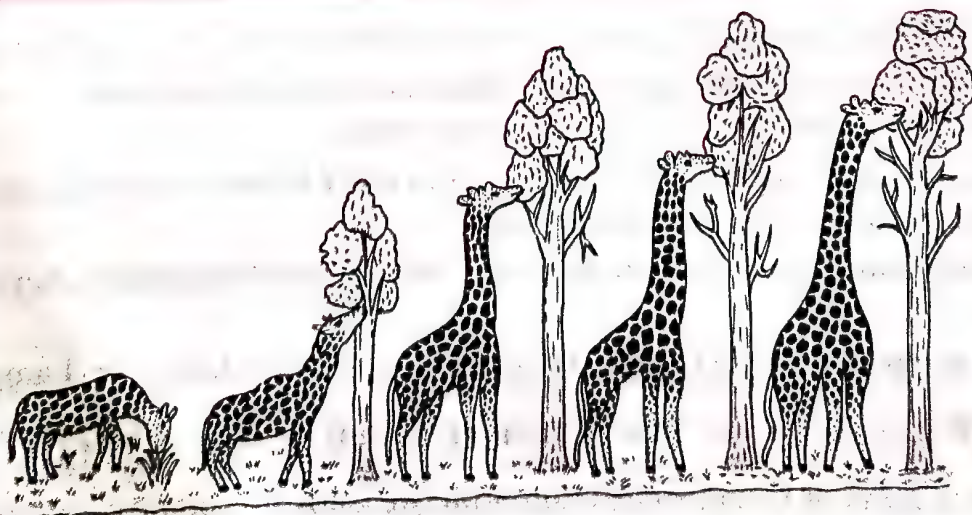


Fig. 7.40. Diagram showing elongation of neck in giraffe according to Lamarck.

(ii) **Webbed Toes of Aquatic Birds.** Aquatic birds like ducks have been evolved from the terrestrial ancestors.

(iii) **Disappearance of Limbs in Snakes.** The snakes have been evolved from lizard like ancestors which were having two pairs of limbs.

(iv) **Flightless Birds.** The ancestors of these birds (e.g., Ostrich) were capable of flying, but due to some environmental factors they had plenty of food and were well protected. So they did not use their wings and that is why the latter became vestigial.

(v) **Deer.** The ancestors of deer were not having so much speed in running, but as they needed protection from other animals of that time they started running, due to which present speed was achieved by the deer.

(vi) **Cave Dwellers.** The ancestors of cave dwellers had normal eye sight. On account of living under continuous dark conditions, the animal lost their power to see.

Criticism of Lamarckism

(Evidences Against the Inheritance of Acquired Characters)

The first proposition of the theory does not have any ground because there is no vital force in organisms which increases their body parts. As regards the second proposition, the environment can affect the animal but it is doubtful that a new need forms new structures. The third proposition, the use and disuse of the organs is correct up to some extent. The fourth proposition regarding the inheritance of acquired characters is disputed.

Mendel's Laws of Inheritance and Weismann's Theory of Continuity of Germplasm (1892) discarded Lamarck's concept of inheritance of acquired characters.

(i) **Theory of Continuity of Germplasm.** August Weismann (1834-1914), a German biologist, was the main opposer of the inheritance of acquired characters. He put forward the **theory of continuity of germplasm**. According to Weismann, the characters influencing the germ cells are only inherited. There is a continuity of germplasm (protoplasm of germ cells) but the somato-plasm (protoplasm of somatic cells) is not transmitted to the next generation hence it does not carry characters to next generation. Weismann cut off the tails of rats for as many as 22 generations and allowed them to breed, but tailless rats were never born.

(ii) Boring of pinna (external ear) and nose of Indian women is never inherited to the next generations.

(iii) The wrestler's powerful muscles are not transmitted to the offspring.

(iv) European ladies wear tight waist garments in order to keep their waist slender but their offspring at the time of birth have normal waists.

(v) Chinese women used to wear iron shoes in order to have small feet, but their children at the time of birth have always normal feet.

(vi) Circumcision of penis is in Jews and Muslims but it is not inherited to the next generation.

(vii) Dull progeny of Nobel Prize winners can not be explained by Lamarckism.

Evidences in Favour of the Inheritance of Acquired Characters

(i) **Formation of Germ Cells from Somatic Cells.** In certain cases *somatic cells can produce the germ cells*, which is against Weismann's theory of continuity of germplasm. This occurs in vegetative propagation in plants and regeneration in animals.

(ii) **Effect of Environment directly on Germ Cells.** Tower exposed the young developing Potato Beetles to extremes of temperature and humidity at the time of the development of their reproductive organs. This did not produce any change in the beetles themselves. Their offspring, however, had colour variations, which were passed on to the succeeding generations. Tower's observations indicate *direct effect of environment on germ cells*.

(iii) **Effect of Radiation.** Exposure of organisms to high energy radiations (ultra-violet rays, X-rays, gamma rays, etc.) or feeding them with mutagenic chemicals, produces sudden inheritable variations or mutations. For example, **Auerbach *et al*** obtained a number of mutations and chromosome aberrations in *Drosophila* with the help of mustard gas.

(iv) **Effect of Chemicals.** There is no isolation of somatic and germ cells. Rather one part of the body affects other parts of the body through chemicals called **hormones**. Change in the secretion of hormones results in the change of different parts of the body.

Neo-Lamarckism

Modified form of Lamarckism is called Neo-Lamarckism (*neo* = new). Neo-Lamarckism proposes that

- (i) Environment does influence an organism and change its heredity.
- (ii) At least some of the variations acquired by an individual can be passed on to the offspring.
- (iii) Internal vital force and appetency do not play any role in evolution.
- (iv) Only those variations are passed on to the offspring which also affect germ cells or where somatic cells give rise to germ cells.

Evidences in favour of the inheritance of acquired characters support the Neo-Lamarckism.

Differences between Lamarckism and Neo-Lamarckism	
Lamarckism	Neo-Lamarckism
1. It is the original theory given by Lamarck.	1. It is a modification of the original theory of Lamarck in order to make it more suitable to modern knowledge.
2. The theory lays stress on internal vital force, appetency and use and disuse of organs.	2. Neo-Lamarckism does not give any importance to these factors.
3. It believes that change in environment brings about a conscious reaction in animals.	3. The theory stresses on the direct effect of changed environment on the organisms.
4. According to Lamarckism the acquired characters are passed on to the next generation.	4. Normally only those modifications are transferred to the next generation which influence germ cells or where somatic cells give rise to germ cells.

Darwin's Theory of Natural Selection

Historical Aspect

In 1831, **Darwin** got an opportunity to travel on **H.M.S. Beagle** (a ship in which Charles Darwin sailed around the world) for a voyage of world exploration. The voyage lasted for five years (1831–1836). During that period Darwin explored the fauna and Flora of a number of continents and islands. Later Beagle was sailed to the **Galapagos Islands**. Galapagos islands consist of 14 main islands and numerous smaller islands which lie on the equator about 960 Km off the West Coast of South America in the Pacific ocean. These islands are

volcanic in origin and are called "a living laboratory of evolution. Darwin visited these islands in 1835 and spent a month there. He observed great variations among the organisms that lived on these islands.

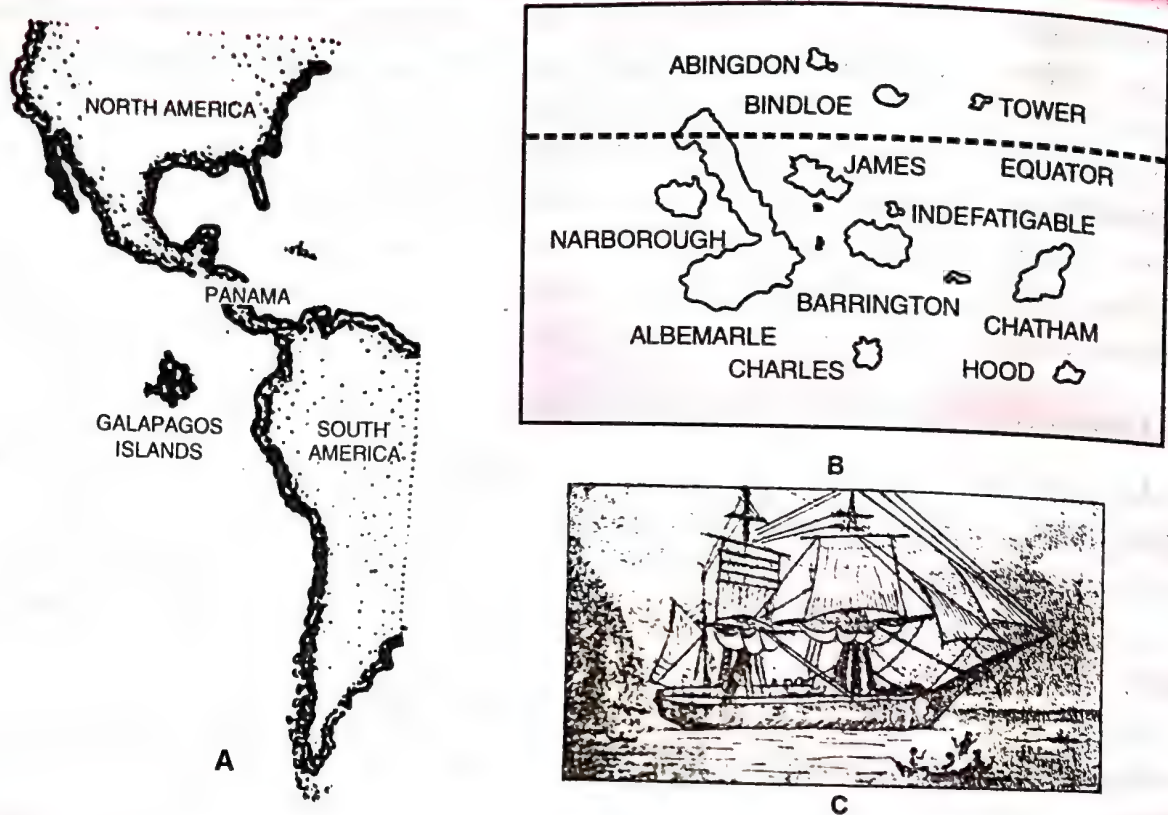


Fig. 7.41. A, Location of Galapagos islands. B, Galapagos islands enlarged. C, H.M.S. Beagle.

Darwin noticed giant tortoises, (Sp.: *galapago*— old spanish name for tortoise), metre-long marine and land iguanas, many unusual plants, insects, lizards, sea shells and birds on Galapagos islands. These giant tortoises may weigh as much as 275 kg, grow to 183 cm in length and attain an age of 200 to 250 years. The Spanish word for tortoise, *galapago*, gives the islands their name. Birds of Galapagos islands influenced Darwin to think about the evolutionary change. These birds were called **finches**. Finches were designated as **Darwin's finches** by Dr David Lack (1947).

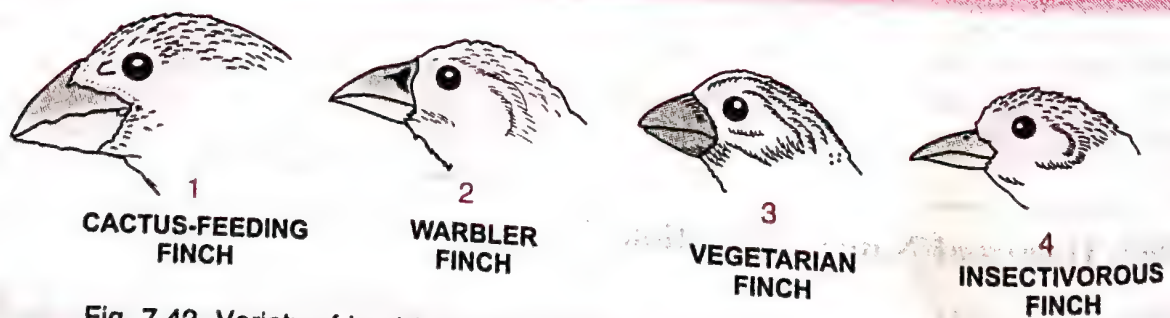


Fig. 7.42. Variety of beaks of finches that Darwin found in Galapagos Islands.

Charles Robert Darwin returned to England in October 1836 from his 5-year expedition. In 1838 he came across with a book *An Essay on the Principles of Population* written by Thomas Robert Malthus (1766–1834) which was published in 1799.

In 1798 T.R. Malthus, a British economist, put forward a **theory of human population growth**. (i) He stated that population grows geometrically when unchecked, whereas the means of its subsistence like food grow only arithmetically. (ii) Naturally, after some time an imbalance would occur in the population and the environment. (iii) When the imbalance reaches a certain value, some factors like hunger, epidemics, floods, earthquakes, war, etc. will bring the population to a desired level. Such a population "crash" is called **catastrophic control of population**. These factors were called "**Positive checks**" by Malthus.

While Darwin was busy in formulating his theory of natural selection, he received a brief essay from Alfred Wallace in June 1858. **Alfred Wallace** (1823–1913), a naturalist from Dutch East Indies was working on Malay Archipelago (present Indonesia). The essay was titled "*On the Tendencies of varieties to Depart Indefinitely from the original type*". The thinking of both Darwin and Wallace in respect of organic evolution was similar.

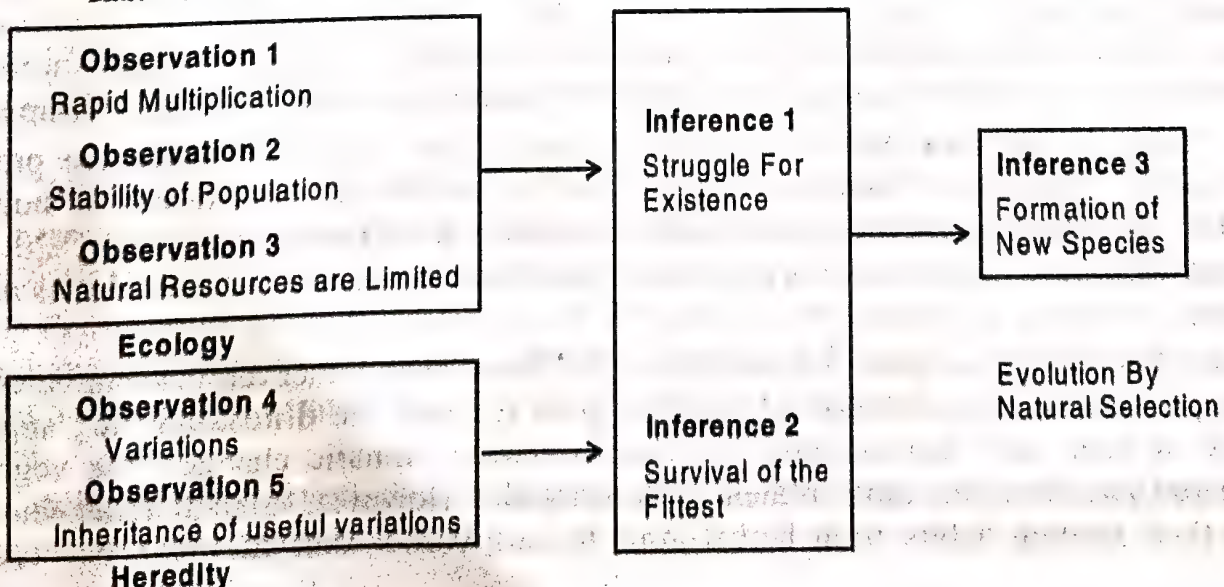
Finally in November 1859 Darwin published his observations and conclusion in the form of book. The full title of his book was *On the origin of species by means of Natural Selection. The Preservation of Races in the Struggle for life*. Actually Darwin gave brief description of origin of species, however he described in detail how populations become well adapted to their environments through natural selection.

Charles Robert Darwin returned to England in October 1836 from his 5-year expedition. In 1838 he came across with a book **An Essay on the Principles of Population** written by **Thomus Robert Malthus** (1766–1834) which was published in 1799. In 1798 T.R. Malthus, a British economist, put forward a **theory of human population growth**. Darwin was influenced by Malthus's theory of human population growth.

The Principle of Natural Selection

The principle of natural selection stems from five important observations and three inferences (Ernst Mayr 1982) which have been mentioned below.

Table 7.2. Five observations and Three Inferences of Natural Selection



Charles Robert Darwin.
(1809–1882)



Alfred Russel Wallace
(1823–1913).

Thus natural selection occurs through an interaction between the environment and the variability inherent in the population.

Salient Features of Darwin's Theory of Natural Selection

The main features of the theory of Natural Selection are as follows :

1. **Over production (Rapid Multiplication).** All organisms possess enormous fertility. They multiply in geometric ratio. Some examples are cited below:

Insects lay hundreds of eggs. A **cod-fish** lays several hundred eggs at a time. A female **rabbit** gives birth to six young ones in one litter and produces four litters in a year. Six-month-old rabbit is capable of reproduction. If all the rabbits survived and multiplied at this rate, their number would be very large after some time. Each pair of mice produces dozens of young ones. It is assumed that **elephant** is the slowest breeder, which matures at the age of 30 years and lives for about 90 years. Each female gives rise to about six offspring.

Thus some organisms (living beings) produce more offspring and others produce fewer offspring. This is called **differential reproduction**.

2. **Limited Food and Space.** Despite of rapid multiplication of all types of species, food and space and other resources remain limited. They are not liable to increase.

3. **Struggle for Existence.** The struggle for existence can be of three types.

(i) *Intraspecific Struggle.* It is the struggle between the individuals of the same species because their requirements like food, shelter, breeding places, etc. are similar. Many human wars are the examples of intraspecific struggle. *Cannibalism* (eating the individuals of its own species) is another example of this type of struggle.

(ii) *Interspecific Struggle.* It is the struggle between the members of different species. This struggle is normally for food and shelter. For example, a fox hunts out a rabbit, while the fox is preyed upon by a tiger.

(iii) *Environmental Struggle.* It is the struggle between the organisms and the environmental factors, such as drought, heavy rains, extreme heat or cold, earthquakes, diseases, etc. Thus, climate and other natural factors also help in restricting the number of individuals of particular species.

4. **Variations.** Except the identical twins, no two individuals are similar and their requirements are also not exactly the same. It means there are differences among the individuals. These differences are called variations. Due to the variations some individuals would be better adjusted towards the surroundings than the others. Adaptive modifications are caused through the struggle for existence. *According to Darwin, the variations are gradual (continuous)* and those which are helpful in the adaptations of an organism towards its surroundings would be passed on to the next generation, while the others disappear.

5. **Natural Selection (Survival of the Fittest).** The organisms which are provided with favourable variations would survive, because they are the fittest to face their surroundings, while the unfity are destroyed. Originally it was an idea of **Herbert Spencer (1820-1903)** who used the phrase '*the survival of the fittest*' first time. While Darwin named it as *natural selection*.

To explain the phenomenon of survival of the fittest, the extinct reptiles can be cited as an example. During the evolution of reptiles, giant reptiles, the **dinosaurs** etc., appeared. Majority of them were herbivorous, but due to certain climatic changes, the vegetation disappeared and, therefore, most of them became extinct. However, small animals who could change their feeding habits from herbivorous to carnivorous diet survived, because they

could easily get adapted to the changed environment. These, therefore, would survive more and hence were selected by nature. Darwin called it natural selection and implied it as a mechanism of evolution. Alfred Wallace a naturalist who worked in Malay Archipelago had also come to similar conclusions around the same time.

6. Inheritance of useful variations. The organisms after getting fitted to the surroundings transmit their useful variations to the next generation, while the non-useful variations are eliminated. Darwin could not differentiate between continuous and discontinuous variations. In this respect, Darwin agreed with Lamarck's views, because according to Darwin acquired characters which are useful to the possessor could be inherited.

7. Formation of new species. Darwin considered that useful variations are transmitted to the offspring and appear more prominently in succeeding generations. After some generations these continuous and gradual variations in the possessor would be so distinct that they form a new species.

Criticism of The Natural Selection Theory

(Objections Against The Natural Selection Theory)

The natural selection theory does not explain the following :

1. **Inheritance of small variations** which are not useful for the possessor.
2. **Over-specialization of some organs** such as tusks of elephants and antlers of deer.
3. **Vestigial organs** are present in some animals when they have no function ?
4. **Arrival of the fittest** is not explained by this theory.
5. **Degeneration of certain organs** in animals is not explained by this theory.
6. **Discontinuous Variations.** The theory fails to explain the cause of sudden changes in the body. *The main drawback of Darwin's theory was lack of the knowledge of heredity and that is why he could not explain that how the variations are caused.*

Darwin himself was conscious of the inadequacies of his theory, when he remarked that, *"I am convinced that natural selection has been the most important but not the exclusive means of modifications."*

Evidences in Favour of Natural Selection

1. **Rate of Reproduction.** Rate of reproduction is many times higher than the rate of survival in all organisms.
2. **Limitation of Resources.** Food, space and other resources are limited.
3. **Struggle for Existence.** Competition or struggle for existence is seen in all organisms.
4. **Abundance of Variations.** Variations are so abundant in nature that no two individuals of a species are similar, not even the monozygotic twins (they possess some dissimilarities due to their environment).
5. **Production of New Varieties of Plants and Animals by Artificial Selection.** When man can produce various new varieties of plants and animals in a short period, nature with its vast resources and long time at its disposal can easily produce new species by selection.
6. **Mimicry and Protective Colouration.** They are found in certain animals and are products of natural selection.

7. **Correlation between Nectaries of Flowers and Proboscis of Insects (Entomophily).** The position of nectary in a flower and the length of proboscis in pollinating insects are wonderfully correlated.

8. **Pedigrees of Some Animals.** Pedigrees of horses, camels and elephants also support the Natural Selection Theory.

Differences Between Lamarckism and Darwinism

Lamarckism	Darwinism
1. This theory states that there is an internal vital force in all organisms.	1. It does not believe in the internal vital force.
2. Lamarckism considers new needs or desires produce new structures and change habits of the organisms.	2. They do not form part of Darwin's natural selection theory.
3. According to this theory if an organ is constantly used it would be better developed whereas disuse of organ results in its degeneration.	3. An organ can develop further or degenerate only due to continuous variations.
4. It does not consider struggle for existence.	4. Struggle for existence is very important in this theory.
5. All the acquired characters are inherited to the next generation.	5. Only useful variations are transferred to the next generation.
6. Lamarckism does not believe in survival of the fittest.	6. Darwin's natural selection theory is based on survival of the fittest.

Artificial Selection

Man has been taking the advantage of genetic variations for improving the qualities of domesticated plants and animals. He selects the individuals with desired characters and separates them from those which do not have such characters. The selected individuals are interbred. This process is termed as **artificial selection**. Thus this process of selection is done through the agency of man or it is man made. If it is repeated for many generations it produces a new breed with desired characters. If cows with high milk yield are desired, the animal breeders select those cows which produce a large quantity of milk. The calves of high milk-yielding cows are interbred to get the new generation of calves. After repeating this process for a number of generations, a breed of high milk-yielding cows is produced. By artificial selection animal breeders are able to produce improved varieties of different kinds of domestic animals (i.e.,

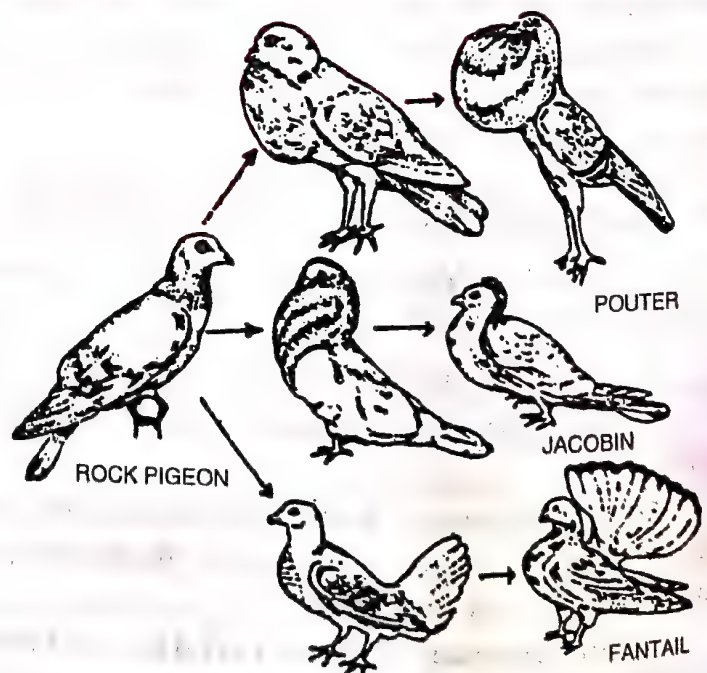


Fig. 7.43. Breeds of domestic pigeon formed from the wild rock pigeon.

of different kinds of domestic animals (i.e.,

dogs, horses, pigeons, poultry, cows, goats, sheep and pigs) from their wild ancestors. Similarly, the plant breeders have obtained improved varieties of useful plants such as wheat, rice, sugarcane, cotton, pulses, vegetables, fruits, etc. Artificial selection is similar to natural selection except that the role of nature is taken over by man and the characters selected are of human use.

Many crop plants like broccoli, cabbage, cauliflower etc. (Fig. 7.44), etc have also been produced through selective breeding.

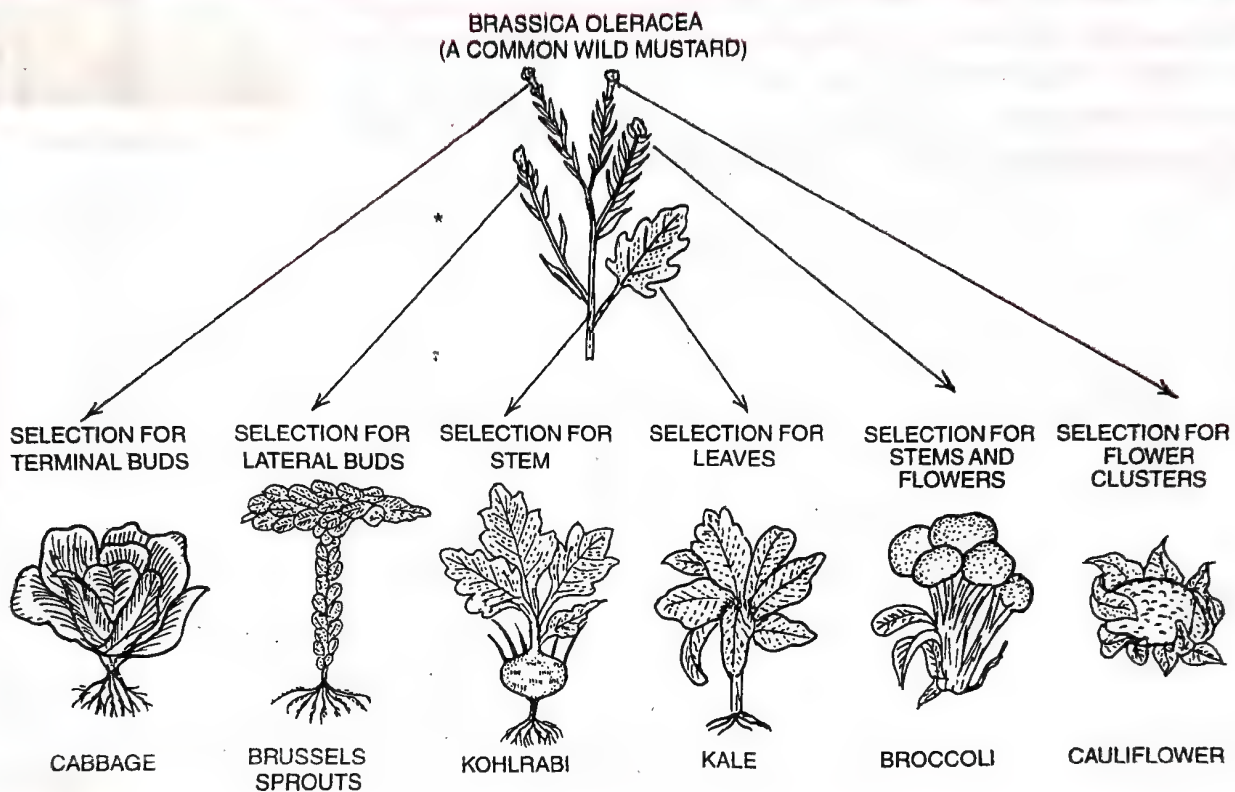


Fig. 7.44. Some crop plants produced by selective breeding.

Differences Between Artificial Selection and Natural Selection

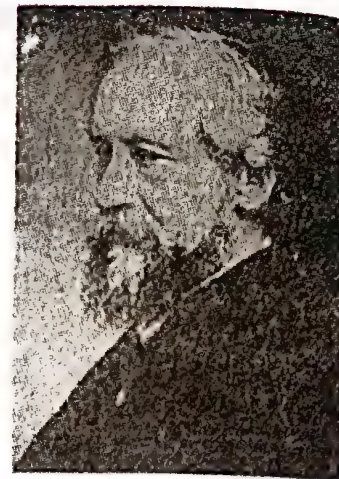
Artificial Selection	Natural Selection
1. It is an artificial process.	1. It is a natural process.
2. It is conducted by man.	2. It is conducted by nature.
3. Traits selected are of human interest.	3. Traits selected are beneficial to the species.
4. Results are achieved in a shorter period.	4. Results are achieved over a long period of time.

Hugo de Vries' Mutation Theory

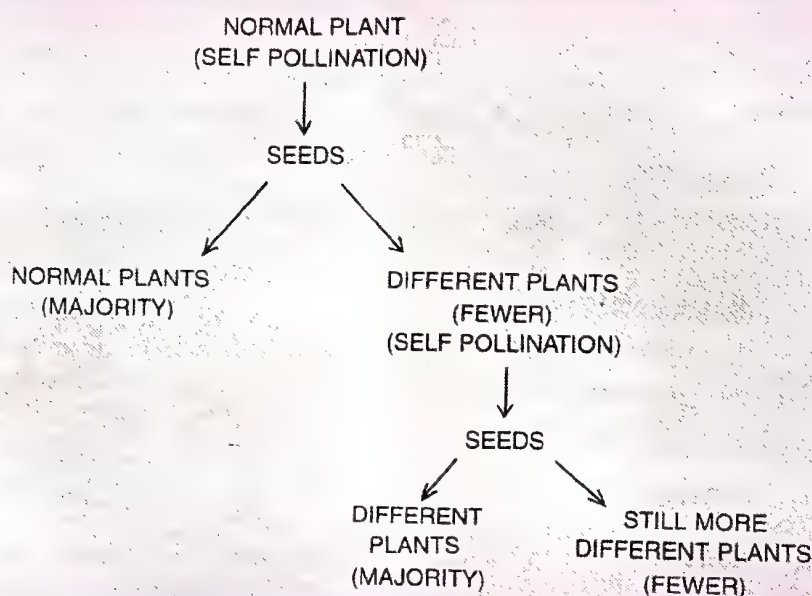
Hugo de Vries (1848—1935), a Dutch botanist, one of the independent rediscoverers of Mendelism, put forward his views regarding the formation of new species in 1901. He also met some of the objections found in Darwin's theory. According to him, new species are not formed by continuous variations but by sudden appearance of variations, which he named as **mutations**. Hugo de Vries stated that mutations are heritable and persist in successive generations.

Experiments Conducted by Hugo de Vries

He conducted his experiments on *Oenothera lamarckiana*, (Evening Primrose) and found several aberrant types. When *O. lamarckiana* was self-pollinated and its seeds were allowed to grow, majority of F_1 plants were similar to the parents, but a few were *different plants*. The different plants were also self-pollinated and when their seeds were sown, the majority of the plants were similar to the parents while a few were still more different plants and this continued generation after generation. These plants appeared to be new species, Hugo de Vries suggested from his experiments that new types of inherited characteristics may appear suddenly without any previous indication of their presence in the race.



Hugo de Vries.



Hugo de Vries believed that mutation causes evolution and not the minor heritable variations which was mentioned by Darwin. Mutations are random and directionless while Darwin's variations are small and directional. According to Darwin evolution is gradual while Hugo de Vries believed that mutation caused species formation and hence known as **saltation** (single step large mutation).

Salient Features of the Mutation Theory

On the basis of above observations, Hugo de Vries (1901) put forward a theory of evolution, called **mutation theory**. The theory states that evolution is a jerky process where new varieties and species are formed by mutations (discontinuous variations) that function as raw material of evolution. The salient features of mutation theory are:

1. Mutations or discontinuous variations are the raw material of evolution.
2. Mutations appear all of a sudden. They become operational immediately.
3. Unlike Darwin's continuous variations or fluctuations, mutations do not revolve around the mean or normal character of the species.
4. The same type of mutations can appear in a number of individuals of a species.
5. All mutations are inheritable.
6. Mutations appear in all conceivable directions.

7. Useful mutations are selected by nature. Lethal mutations are eliminated. However, useless and less harmful ones can persist in the progeny.

8. Accumulation of variations produce new species. Sometimes a new species is produced from a single mutation.

9. Evolution is a jerky and discontinuous process.

Evidences in Favour of the Mutation Theory

(1) Mutations are actually the source of all variations and hence fountain head of evolution. (2) Mutation theory can explain both progressive and retrogressive evolution. (3) As the ratio of mutations is not the same in all individuals and their parts, mutation theory can explain the occurrence of both changed and unchanged forms. (4) A number of mutations have appeared in the past. Mutations are also induced. They have given rise to new varieties. (a) Ancon Sheep (Fig. 7.45) is a short-legged variety which appeared suddenly in Massachusetts in 1791. (b) Hornless Cattle developed as mutation from the horned cattle in 1889. (c) A single mutation can give rise to a new variety and even species of plants, e.g., Delicious Apple, *Cicer gigas*, Noval Orange, Red Sunflower. (d) Hairless cats and double-toed cats have developed through mutations.

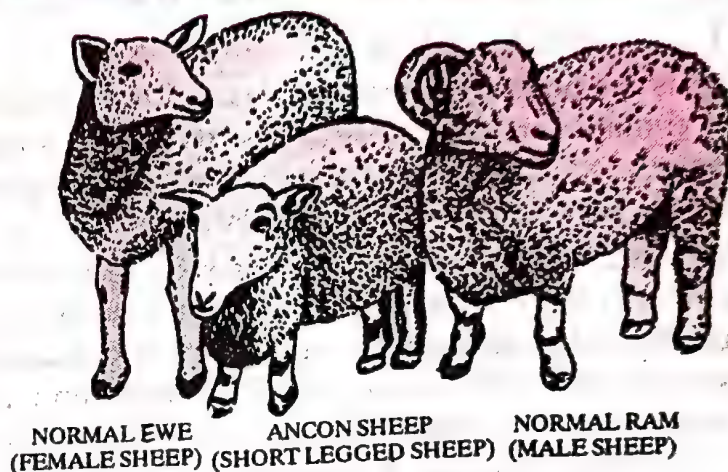


Fig. 7.45. Ancon sheep with its normal parents.

Evidences Against the Mutation Theory (Criticism of the Mutation Theory)

(1) *Oenothera lamarckiana* of Hugo de Vries was not a normal plant but a complex heterozygous form with **chromosome aberrations**. (2) Natural mutations are not common as Hugo de Vries thought them to occur. (3) Most of the mutations are negative or retrogressive. (4) Mutations are generally recessive while traits taking part in evolution are usually dominant. (5) Mutation theory cannot satisfactorily explain the development of mimicry, mutual dependence of flowers and pollinating insects. (6) This theory does not explain the role of nature.

Significance of Hugo de Vries' Mutation Theory

This Theory gives direct attention to the mutations. But later on it was thought that evolution cannot occur by mutations alone. Natural selection and isolation of mutants were also essential for evolution.

Differences Between Hugo de Vries' Mutation and Darwinian Variation

Hugo de Vries' Mutation	Darwinian Variation
1. Mutations appear all of a sudden.	1. Darwinian variations are gradual.
2. Mutations are the raw material of evolution.	2. Continuous variations are the basis of evolution.
3. Mutations are due to change in genetic make-up.	3. Genes were not known to Darwin.

Modern Concept of Evolution/Synthetic Theory of Evolution

The present concept of evolution is a modified form of the Darwin's theory of natural selection and often called **Neo-Darwinism**. According to it only genetic variations (mutations) are inherited and not all variations as held by Darwin. Thus modern concept of evolution is synthesis of Darwin's and Hugo de Vries' theories. This is also called **Synthetic Theory of Evolution**.

The synthetic theory of evolution is the result of the work of a number of scientists namely **T. Dobzhansky, R.A. Fisher, J.B.S. Haldane, Sewall Wright, Ernst Mayr and G.L. Stebbins**. Stebbins in his book, *Process of Organic Evolution*, discussed the **synthetic theory**. Synthetic theory of evolution is most accepted theory of evolution.

1. Genetic Variation in Population

It is the population that evolves and not its individual members. The individual's role in the evolutionary process is to pass its genetic variation to its offspring. Evolution occurs through the accumulation of genetic variations in population over long periods of time. The change in genes occurs in the following ways.

(i) **Mutations**. Mutations are sudden heritable changes. Hugo de Vries believed that it is mutation which causes evolution and not the minor variations (heritable) that Darwin talked about. According to Darwin evolution was gradual while Hugo de Vries said that mutation caused speciation and hence called the **saltation** (single step large mutation). Mutations are of two types: chromosomal mutations and gene mutations.

(a) **Chromosomal Mutations**. These are due to changes in chromosome number and changes in structure.

Changes in Chromosome Number. These mutations are caused by changes in the number of chromosomes. They are of further two types : polyploidy and aneuploidy (a) **Polyploidy**. It is increase in number of chromosome sets. Example : triploidy ($3n$), tetraploidy ($4n$), pentaploidy ($5n$), hexaploidy ($6n$). Increase in the number of the same genome is known as **autopolyploidy** (e.g., AAAA). Increase in number of chromosome sets due to coming together of genomes of two or more organisms is called **allopolyploidy**. It is also termed as interspecific polyploidy. (b) **Aneuploidy**. It is a mutation in which a numerical change occurs in the chromosome number of the genome monosomy ($2n-1$), nullisomy ($2n-2$), trisomy ($2n+1$), tetrasomy ($2n+2$), etc.

Structural Changes in Chromosomes (Chromosomal Aberrations). When the change occurs in the morphology of chromosomes it is called chromosomal aberration. These are of four types, **duplication** (doubling of a segment), **deficiency** (deletion of a segment), **translocation** (passage of segment of a chromosome to a nonhomologous chromosome) and **inversion** (reversal in the order of genes).

(b) **Gene Mutations**. When the changes are in gene structure and expression due to **addition, deletion substitution or inversion** of nucleotides these are called **gene mutations**. The frequency of gene mutations varies from gene to gene. Rate of gene mutation is increased by the presence of radiations and certain chemicals called **mutagens**. Mutated genes add new alleles to the gene pool. **Gene pool** is the sum total of all the different genes and their alleles present in a population. It is the gene pool that evolves as new genes, i.e., alleles, are added or removed, then is the raw material for evolutionary change. The accumulation of many mutations may add up to large-scale changes which finally lead to formation of new species.

Gene mutation that involves change in a single base pair of DNA is called **point mutation**. The gene mutations which involve change in more than one base pairs or the entire gene are termed **gross mutations**.

(ii) **Gene Recombination**. It occurs due to the following reasons. (a) Dual parentage (b) Independent assortment of chromosomes (c) Crossing over during meiosis. (iv) Random fusion of gametes (v) Formation of new alleles. Since it adds new alleles and combination of alleles to the gene pool it is important process during evolution which causes variations.

(iii) **Gene Migration (Gene flow)**. The movement of individuals from one place to another is called migration. If the migrating individuals breed within the new population, the immigrants will add new alleles to the local gene pool of the host population. This is called **gene migration**. Sometimes two populations of a species which were separated come to close due to migration. The genes of two populations intermingle through breeding and the result causes variations in the offspring.

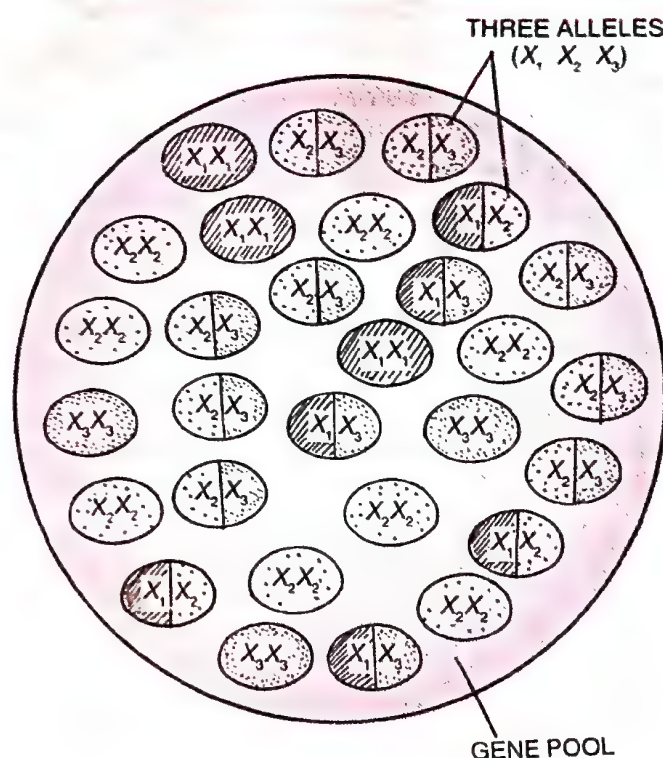


Fig. 7.46. Alleles in a Gene pool.

(iv) **Genetic Drift (Sewall Wright Effect)**. Genetic drift is drastic change in allele frequency when the population size becomes very small. Therefore, it alters the gene frequency of remaining population which causes variation. It is named after the American geneticist Sewall Wright who realised its evolutionary significance. Although genetic drift occurs in all populations, its effects are most marked in very small isolated population. Two important examples of genetic drift are founder effect and bottleneck effect.

(a) **Founder Effect or Founder Principle**. It is an important example of genetic drift in human population. It is noted when a small group of persons called **founders**, leave their homes to find a new settlement, the population in a new settlement may have different genotype frequencies from that of the parent population. Formation of a different genotype in new settlement is called the **founder effect**. Sometimes they form a new species.

(b) **Bottleneck Effect**. The term was introduced by Stebbins for annual and biannual cycle phenomenon of decrease and increase of a size of a population. When the population is at decline, the number of individuals may reduce to the extent that the small group of population constituting the population becomes isolated and restricted in distribution. These are then exposed to random genetic drift resulting in the fixation of certain genes. Thus the population re-establishes its former richness. Such reduction in allele frequencies is called a **genetic bottleneck effect** which often prevents the species from extinction (Fig. 7.47).

Significance of genetic drift. Genetic drift is an evolutionary force. Most interbreeding animal populations are small. Genetic drift helps the populations to become different because of the probability that each population fixes different genotypes by chance.

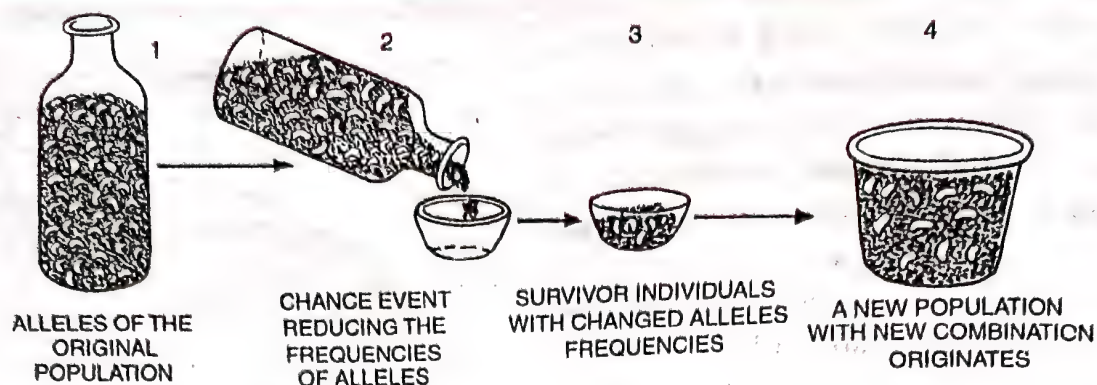


Fig. 7.47. Explaining bottleneck effect-frequencies of two alleles are represented by black and white colours.

Difference Between Gene Migration (Gene flow) and Genetic Drift

<i>Gene Migration (Gene flow)</i>	<i>Genetic Drift</i>
It is the movement of alleles among populations by the migration of breeding individuals. There can be a constant gene flow between adjacent animal populations due to the migration of organisms.	It is drastic change in allele frequency when the population size becomes very small.

(v) **Nonrandom Mating.** Repeated mating between individuals of certain selected traits changes the gene frequency. The selection of more brightly coloured male bird by a female bird may increase the gene frequency of bright colour in the next generation.

(vi) **Hybridization.** It is the crossing of organisms which are genetically different in one or more traits (characters). It helps in intermingling of genes of different groups of the same variety, species and some times different species.

All the above factors produce genetic variation in sexual reproduction.

2. Isolation

Isolation is the prevention of mating amongst interbreeding groups due to physical (e.g., geographical, ecological) and biotic (e.g., physiological, behavioural, mechanical, genetic) barriers. Any factor which prevents interbreeding is known as isolating mechanism. Isolating mechanism prevents interbreeding through three methods (Mayr, 1963)— (i) Restriction to random dispersal, (ii) Restricting to random mating and, (iii) Restriction to fertility. Reproductive isolation is described here.

Reproductive Isolation. Reproductive isolation is the prevention of interbreeding between the populations of two different species. According to Mayr reproductive isolating mechanisms are the *biological properties of individuals which prevent the interbreeding of naturally sympatric populations*. It maintains the characters of the species but can lead to the origin of new species. Two main subtypes may be considered under reproductive isolation : *Premating isolation* and *postmating isolation*.

(a) **Premating or Prezygotic Isolation.** The principal factors operating under this sub-type are :

Mechanical Isolation. The morphology of genitalia, or reproductive organs (of male and female) of the two populations may be very complicated and unlike; with the result, copulation between males of one population and females of another, fails to occur. The mechanical isolation is common among insect species. In certain plants, the flower structure is very complicated, and this prevents cross-pollination between the related species.

Psychological Isolation. The behavioural differences restrict random mating of male and female individuals of different species. The behavioural differences have been observed particularly during *courtship*, which is an important sexual phenomenon, involving a series of stimuli and responses, between the mating partners. Songs of birds, courtship behaviour etc. may also play an effective role in mating.

Seasonal Isolation. This also serves as an effective barrier to gene flow. Here, the breeding period of mating individuals is different for different species. Several examples can be cited from birds to illustrate seasonal isolation due to difference in the breeding period.

Gametic Isolation. In free living aquatic forms, where the fertilization is external, the gametes produced by different species usually do not attract each other and this kind of barrier is known as gametic isolation.

(b) **Post-mating or Postzygotic Isolation.** The main factors operating under this sub-type are:

Incompatibility. In some instances, mating takes place between populations, but fertilization may not take place; or even fertilization may occur, but no hybrid progeny will be formed. In plants, pollen tube fails to grow and will not reach any ovule.

Hybrid Inviability. Here, normal fertilization occurs, and hybrid offspring is also formed, but the hybrid has reduced viability. The hybrid inviability may appear at any stage of development.

Hybrid Sterility. In many cases, hybrids may be vigorous and live to sexual maturity, but are sterile. Horses and donkeys are two different species; a hybrid mule is produced from the mating of a male donkey and a mare (female horse). Similarly mating between stallion (male horse) and female donkey, results in a hybrid called hinny. Both mule and hinny are sterile.

Hybrid Breakdown. In some instances, not only vigorous F_1 hybrids are produced, but also, these hybrids produce F_2 individuals of backcross progeny. Unfortunately, hybrid breakdown results in the F_2 and backcross generations, as these individuals have reduced vigour of fertility or both.

The achievement of reproductive isolation through the combined effects of isolating mechanisms appears to be an important step in speciation.

Examples of species that breed in captivity and produce fertile hybrids are (i) African lioness (*Panthera leo*) and Asian tiger (*Panthera tigris*) produce 'tigons', (ii) the polar bear and the Alaskan brown bear (iii) mallard (a duck) and the pintail duck and (iv) the platy and swordtail fishes. It is important to note that these species do not interbreed in natural condition.

3. Heredity

The transmission of characteristics or variations from parent to offspring is called heredity which is an important mechanism of evolution. Organisms possessing hereditary characteristics that are helpful, either in the animal's native environment or in some other environment, are favoured in the struggle for existence. Thus, the offspring are able to benefit from the advantageous characteristics of their parents.

4. Natural Selection

This is the most widely accepted theory concerning the principal causal mechanism of evolutionary change propounded by Charles Darwin and Alfred Russel Wallace. It results from the **differential reproduction** (some members of a population produce abundant offspring, some only a few and still others none), one phenotype as compared with other phenotypes in the same population. This determines the relative share of different genotypes which individuals possess and propagate in a population. According to Darwinism survival and fertility mechanism that affect the reproductive success or promote differential reproduction are called selection. But according to modern views, selection is the consistent differences in the contribution of various genotypes to the next generation.

5. Speciation (Origin of new species)

The populations of a species present in the different environments and are separated by geographical and physiological barriers, accumulate different genetic differences (variations) due to mutations, recombination, hybridization, genetic drifts and natural selection. These populations, therefore, become different from each other morphologically and genetically, and they become reproductively isolated, forming new species.

Types of Natural Selection (Fig. 7.48)

Selection is the process by which those organisms which appear physically, physiologically and behaviourally better adapted to the environment survive and reproduce; those organisms not so well adapted either fail to reproduce or die. The former organisms pass on their successful characters to the next generation, whereas the latter do not. Selection depends upon the existence of phenotypic variation within the population and is part of the mechanism by which a species adapts to its environment.

A population has three types of individuals on the basis of their size—average-sized, large-sized and small-sized. There are three types of selection process occurring in natural and artificial populations and they are described as stabilising, directional and disruptive.

1. **Stabilising Selection** (Balancing Selection). *This type of selection favours average sized individuals while eliminates small sized individuals. It reduces variation and hence does not promote evolutionary change. However, it maintains the mean value from generation to generation. If we draw a graphical curve of population, it is bell-shaped.*

Example. It occurs in all populations and tends to eliminate extremes from the population, e.g., there is an optimum wing length for a hawk of a particular size with a certain mode of life in a given environment. Stabilising selection, operating through differences in breeding potential, will eliminate those hawks with wing spans larger or smaller than this optimum length.

2. **Directional Selection** (Progressive Selection). In this selection, the *population changes towards one particular direction*. It means this type of selection favours small or large-sized individuals and more individuals of that type will be present in next generation. The mean size of the population changes.

Examples. Evolution of DDT resistant mosquitoes, industrial melanism in peppered moth and evolution of giraffe.

3. **Disruptive Selection** (Diversifying Selection). This type of selection favours both small-sized and large-sized individuals. It eliminates most of members with mean expression, so produces two peaks in the distribution of the trait that may lead to development of two

different populations. This kind of selection is *opposite of stabilizing selection* and is rare in nature but is very important in bringing about evolutionary change.

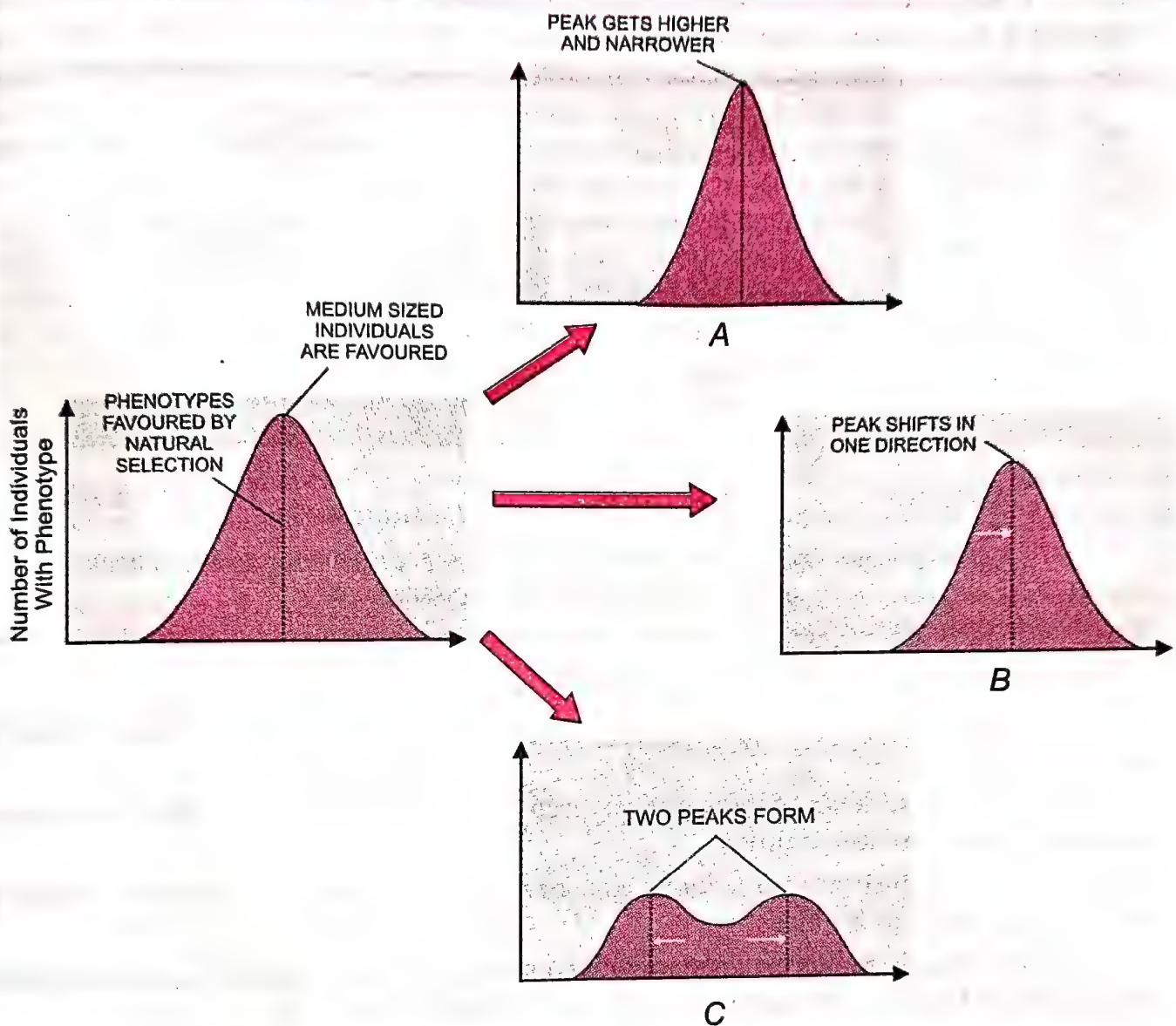


Fig. 7.48. Diagrammatic representation of the operation of three types of natural selection on different traits : (A) Stabilising (B) Directional and (C) Disruptive.

Example. Stebbins and his coworkers studied an example of disruptive selection in a population of sunflowers in the Sacramento Valley of California over a period of 12 years. In the beginning the genetically variable population of these sunflowers was a hybrid between two species. After five years this population had split into two subpopulations separated by a grassy area. One of these subpopulations occupied a relative dry site and other occupied comparatively wet site. During the next seven years the size of the population fluctuated greatly in response to differences in rainfall, but the differences between the two subpopulations were maintained.

Examples of Natural Selection

1. **Industrial Melanism.** It is an adaptation where the moths living in the industrial areas developed melanin pigments to match their body to the tree trunks. The problem of

industrial melanism in moths has been originally studied by **R.A. Fischer** and **E.B. Ford**; and in recent times, by **H.B.D. Kettlewell**. The occurrence of industrial melanism is closely associated with the progress of the industrial revolution in Great Britain, during the nineteenth century. It has occurred in several species of moths. Of these, **peppered moth** (*Biston betularia*) is the most intensely studied.

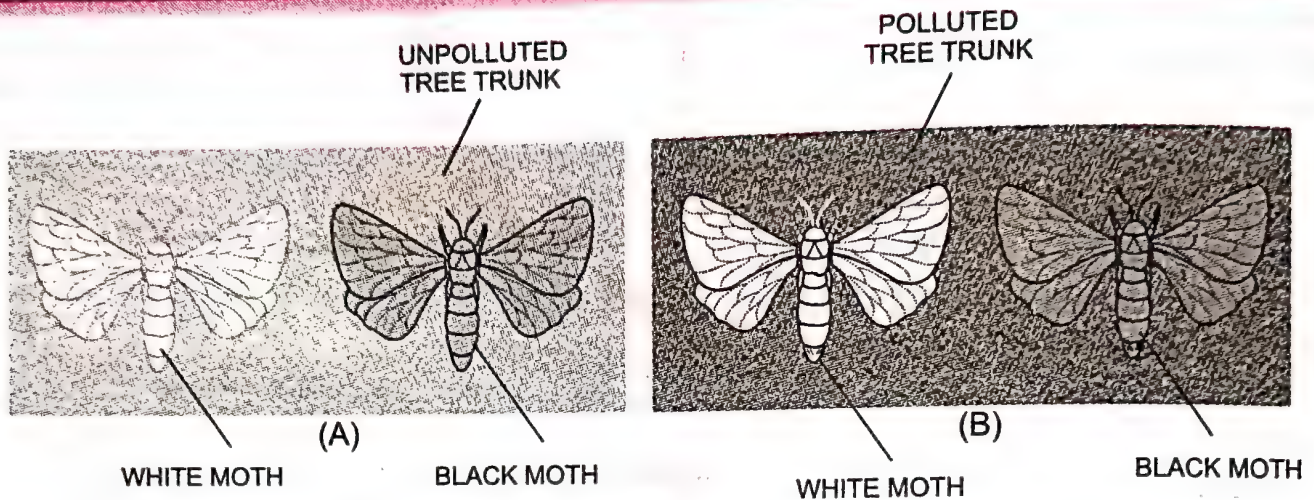


Fig. 7.49. Figure showing white-moth and black-moth (melanised) on a tree trunk.
(A) In unpolluted area (B) In polluted area.

Industrial melanism can be written briefly as follows.

- (i) The peppered moth existed in two strains (forms): light coloured (white) and melanic (black).
- (ii) In the past, bark of trees was covered by whitish lichens, so white moths escaped unnoticed from predatory birds.
- (iii) After industrialisation barks got covered by smoke, so the white moths were selectively picked up by birds.
- (iv) But black moths escaped unnoticed so they managed to survive resulting in more population of black moths and less population of white moths.

Thus *industrial melanism supports evolution by natural selection.*

2. Resistance of insects to Pesticides. The DDT, which came to use in later 1945, was thought to be an effective insecticide against household pests, such as mosquitoes, houseflies, body lice, etc. But, within two to three years of the introduction of this insecticide, new DDT resistant mosquitoes appeared in the population. These mutant strains, which are resistant to DDT, soon became well established in the population, and to a great extent, replaced the original DDT-sensitive mosquitoes.

3. Antibiotic Resistance in Bacteria. This is also true for disease causing bacteria against which we use antibiotics or drugs to kill these bacteria. When a bacterial population encounters a particular antibiotic, those sensitive to it die. But some bacteria having mutations become resistant to the antibiotic. Such resistant bacteria survive and multiply quickly as the competing bacteria have died. Soon the resistance providing genes become widespread and entire bacterial population becomes resistant.

Genetic Basis of Adaptation—The Lederberg Replica Plating Experiment to illustrate Role of Natural Selection (Fig. 7.50). By an Experiment Joshua Lederberg and

Esther Lederberg (1952) were able to show that there are mutations which are actually preadaptive. Generally bacteria are cultivated by plating dilute suspensions of bacterial cells on semi-solid agar plates containing *complete medium* with antibiotic like Penicillin. After some period colonies appear on the agar plates. Each of these colonies develops from a single bacterial cell by mitotic cell divisions. Lederberg inoculated bacteria on an agar plate and obtained a plate with several bacterial colonies. This plate is called as 'master plate'. They then formed several replicas from this master plate. For this, they took a sterile velvet disc, mounted on a wooden block, which was gently pressed on the master plate. Some of the bacteria cells from each colony stuck to the velvet cloth. By pressing this velvet on new agar plates of minimal medium, they were able to obtain exact replicas of master plate. This was due to the fact that the bacterial cells were transferred from one plate to the other by the velvet. After that they tried to make replicas on the agar plates of minimal medium containing an antibiotic penicillin, the replica colonies were not formed. The new colonies that did grow were naturally resistant to streptomycin/penicillin. The new colonies that did not grow were sensitive colonies. Therefore, there was an adaptation in some bacterial cells to grow on a medium containing the antibiotic (penicillin). This proved that mutations had occurred before bacteria were exposed to penicillin.



Joshua Lederberg.

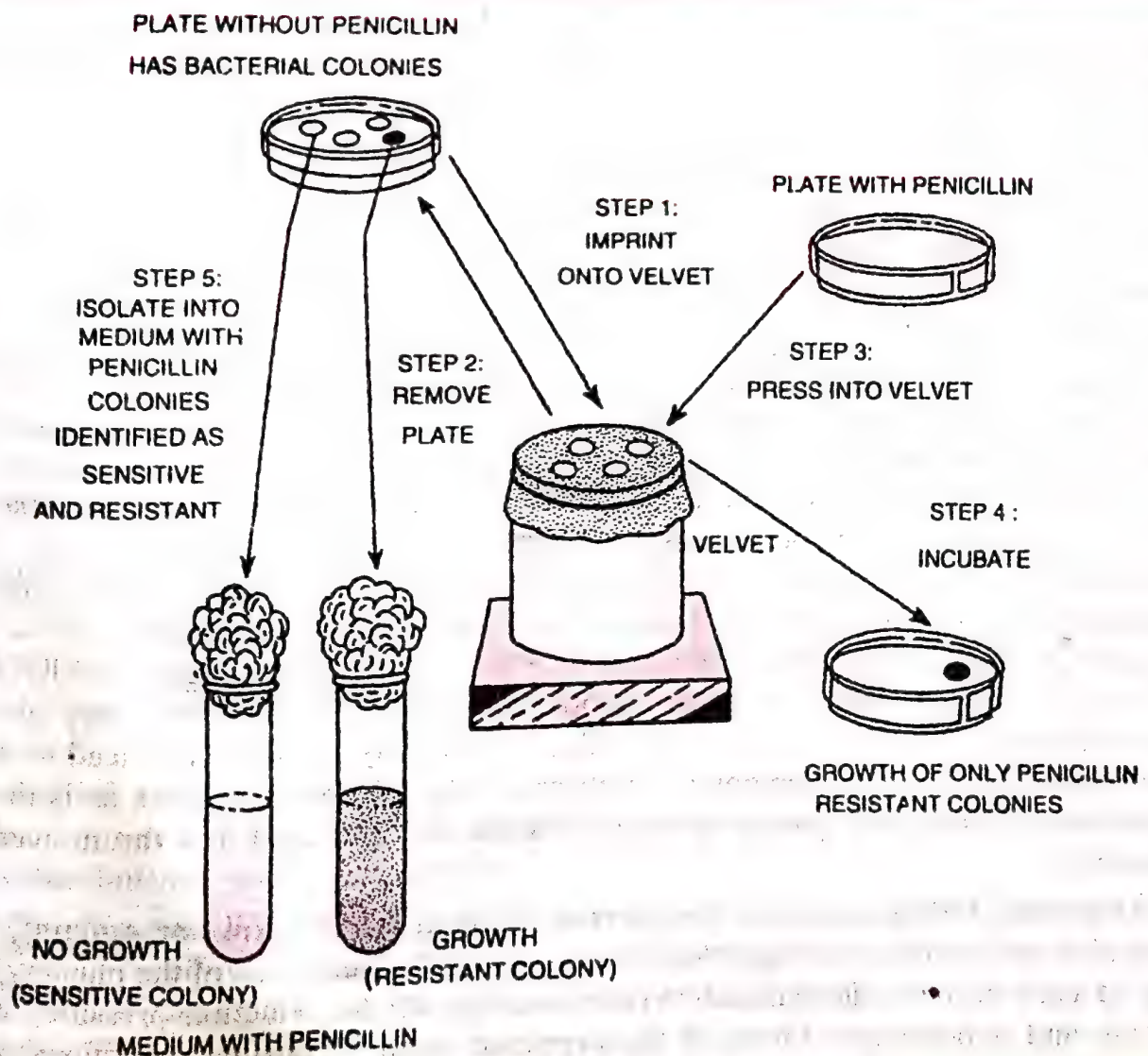


Fig. 7.50. Lederberg's replica plating experiment.

Thus resistant organisms/cells appear in months and years and not centuries. This also shows that evolution is not directed process. It is a stochastic process based on chance events in nature and chance mutation in the organism.

4. **Sickle Cell Anaemia:** One of the best examples has been discovered in the human populations, inhabiting in tropical and subtropical Africa. The *sickle cell gene* produces a variant form of the protein haemoglobin, which differs from the normal haemoglobin by a single amino acid. In people, homozygous for this abnormal haemoglobin, the red blood cells (RBCs) become sickle-shaped, and this condition is described as **sickle cell anaemia**. The people affected by this disease usually die before reproductive age, due to a severe **haemolytic anaemia**. In spite of its disadvantageous nature, the gene has a high frequency in some parts of Africa, where malaria is also in high frequency. Subsequently, it has been discovered that the **heterozygotes for the sickle cell trait are exceptionally resistant to malaria**. Thus in some parts of Africa, people homozygous for the normal gene tend to die of malaria, and those homozygous for sickle cell anaemia tend to die of severe anaemia; while the heterozygous individuals survive and have the selective advantage over either of homozygotes.

Sickle cell anaemia is caused by the substitution of glutamic acid by valine at sixth position of beta chain of haemoglobin.

5. **Glucose 6-Phosphate Dehydrogenase Deficiency (G-6-PD).** It occurs as inborn error of metabolism in some persons. It is also called **favism** because beans cause haemolysis in the patients. Antimalarial drugs like primaquin causes haemolysis in such persons. The haemolysis is due to production of H_2O_2 which is not removed because of Glucose 6-PD deficiency and the result is lack of $NADPH_2$. Malarial parasite can not complete schizogony in Glucose 6-PD deficient patients due to premature death of RBCs.

6. **Genetic Polymorphism.** Polymorphism plays a significant role in the process of natural selection. It is defined as the existence of two or more forms of the same species within the same population and can apply to biochemical, morphological and behavioural characteristics. There are two forms of polymorphism—Balanced polymorphism and Transient polymorphism.

Balanced Polymorphism. This occurs when different forms coexist in the same population in a stable environment. It is illustrated most clearly by the existence of the two sexes in animals and plants. The genotypic frequencies of the various forms exhibit equilibrium since each form has a selective advantage of equal intensity. In humans, the existence of the A, B, AB and O blood groups are examples of balanced polymorphism. Whilst the genotypic frequencies within different populations may vary, they remain constant from generation to generation within that population. This is because none of them has a selective advantage over the other. Statistics reveal that white men of blood group O have a greater life expectancy than those of other blood groups, but, interestingly, they also have an increased risk of developing a duodenal ulcer which may perforate and lead to death. Red-green colour blindness in humans is another example of polymorphism, as is the existence of workers, drones and queens in social insects and pin-eyed and thrum-eyed forms in primroses.

Transient Polymorphism. This arises when different forms or **morphs**, exist in a population undergoing a strong selection pressure. The frequency of the phenotypic appearance of each form is determined by the intensity of the selection pressure, such as the melanic and non-melanic forms of the peppered moth. Transient polymorphism usually applies in situations where one form is gradually being replaced by another.

Differences Between Darwinism and Neo-Darwinism

Darwinism (Natural Selection)	Neo-Darwinism
<ol style="list-style-type: none"> 1. It is the original theory given by Charles Darwin (1859) to explain the origin of new species. 2. According to this theory accumulation of continuous variations causes change in individuals to form new species. 3. It believes in the selection of individuals on the basis of accumulation of variations. 4. Darwinism does not believe in isolation. 5. It can explain the origin of new characters. 6. Darwinism cannot explain the persistence of certain forms in the unchanged condition. 	<ol style="list-style-type: none"> 1. Neo-Darwinism is a modification of the original theory of Darwin to remove its short-comings. 2. Instead of continuous variations mutations are believed to help form new species. 3. Variations accumulate in the gene pool and not in the individuals. 4. Neo-Darwinism incorporates isolation as an essential component of evolution. 5. The theory cannot explain the origin of new characters. 6. The theory can explain the occurrence of unchanged forms over millions of years.

Differences Between Neo-Lamarckism and Neo-Darwinism

Neo-Darwinism	Neo-Lamarckism
<ol style="list-style-type: none"> 1. The theory explains that the number of organisms of different species remain the same despite their high biotic potential and ability to increase by geometrical ratio. 2. It stresses the role of struggle for existence and natural selection in face of limited resources. 3. It explains the role of variations, their origin and accumulation in the formation of new species. 	<ol style="list-style-type: none"> 1. It is silent about high biotic potential and geometrical increase in population. 2. The theory does not touch these aspects of evolutionary forces. 3. The theory considers that the change in environment produces modifications directly due to its effect on germ cells or rarely indirectly through somatic cells.

Species Concept

Evolutionary taxonomists define a species as the *basic unit of classification*. Taxonomists also have used various methods to define a species.

1. **Taxonomic (Morphological) Species.** Davis and Heywood (1963) define species as *assemblage of individuals with morphological features in common and separable from other such assemblages by correlated morphological discontinuities in a number of features*.

2. **Biological Species (Mayr, 1942).** According to biological species concept, species is a population or series of population in which the individual members can interbreed freely with each other but not with other species.

3. **Sibling Species.** When the two species are morphologically almost identical but do not normally interbreed, such species are called **sibling species**. For instance, *Drosophila pseudoobscura* and *Drosophila persimilis* are two species of fruitfly which do not cross-fertilise.

4. **Polytypic Species.** A species having two or more varieties or subspecies is called **polytypic species**. For example, the various species of North American sparrow have been united with the multiple geographical races or subspecies of song sparrow, *Passarella melodia*.

5. **Evolutionary Species.** Many biologists have proposed another concept of species that is evolutionary species concept. In this concept, a species is defined in terms of differences that are not dependent on sexual isolation. The supporters of this concept give more importance to the evolutionary isolation, of which sexual isolation is only one aspect.

6. **Endemic Species.** The species which is restricted to a specific area and not found elsewhere is called **endemic species**.

7. **Synchronic Species.** Species of the same period of time.

8. **Allochronic Species.** Species of different periods of time.

9. **Monotypic Species.** A species without any distinct subdivision or variety.

10. **Allopatric.** A species developed and occurring in an exclusive geographical area.

11. **Sympatric Species.** A species developed due to reproductive isolation and therefore, occurring in overlapping or same area of geographical distribution as its sister species.

12. **Parapatric Species.** A species developed in adjacent geographical areas meeting in very narrow regions of overlap.

Important Characteristics of a Species. The important characteristics of a species may be summarised as follows.

(i) All the members whether present in one or more populations found in different and even remote areas of the globe are derived from a **common ancestor**.

(ii) The members **resemble** one another more than they resemble individuals of other species.

(iii) There is a complete **anatomical similarity**.

(iv) All the members of a species have similar **karyotype**.

(v) There is a broad similarity in **morphological characters**.

(vi) There is **molecular similarity** in the type of proteins, enzymes, hormones and other biochemicals.

(vii) The members are able to **interbreed** freely and produce fertile offspring.

(viii) The members of a species do not interbreed with members of other species, *i.e.*, they are **reproductively isolated**. However, the criterion of reproductive isolation cannot be used in delimiting asexual organisms. Mayr (1987) prefers to use the term **paraspecies** while Ghiselin (1987) uses the term **pseudospecies** for asexual groups.

Speciation

Speciation is the formation of one or more new species from an existing species. A species is a collection of **demes**. The deme is a group of populations with common gene pool.

Types of Speciation. Speciation is of following types.

1. **Allopatric Speciation** (*allos*— other, *patria*— native land). In this type of species formation, a part of the population becomes geographically isolated from the main population. An important example of this type of speciation is formation of Darwin's finches that formed separate species in the Galapagos Islands (Fig. 7.51A).

2. **Sympatric Speciation** (*sym*— together, *patria*— native land). In this type of species

formation, a small segment of the original population becomes isolated reproductively. The reproductive isolation brings about sympatric speciation (Fig. 7.51B).

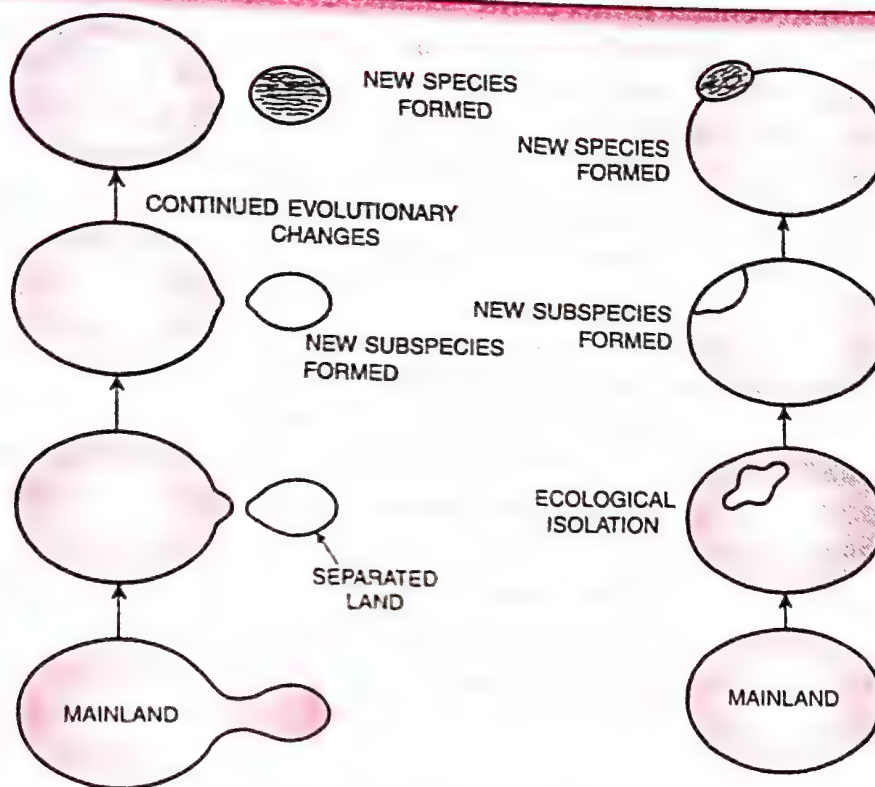


Fig. 7.51. A, Allopatric speciation (hypothetical representation); B, Sympatric speciation (hypothetical representation).

3. Parapatric Speciation. Parapatric speciation takes place when a population of a species enters a new **niche** or habitat. It occurs only at the edge of the parent species range. Two species are produced due to reproductive isolation from single one. Such type of speciation is found in flightless grasshoppers, snails and annual plants.

4. Quantum Speciation. It is the rapid and abrupt mode of species formation. Grant (1971) defined quantum speciation "*the budding off a new and very different daughter species from a semi-isolated peripheral population of the ancestral species*". This type of speciation is based on the observation of **H.L. Carson** on *Drosophila* inhabiting Hawaii islands.

Genetic drift or chance plays a major role in quantum speciation.

Factors Influencing Speciation. Following factors influence the speciation : (i) Mutation (ii) Recombination (iii) Natural selection (iv) Hybridization (v) Genetic drift (vi) Polyploidy (to be described) and (vii) Isolation.

Differences between Allopatric Speciation and Sympatric Speciation	
<i>Allopatric Speciation</i>	<i>Sympatric Speciation</i>
1. It occurs in a spatially, isolated population.	1. It occurs from a segment within a population.
2. The barrier is physical.	2. The barrier is ecological and genetic.
3. There are chances of breakdown of isolating mechanism.	3. Chances of breakdown of isolating mechanism are rare.
4. Speciation is slow.	4. Speciation is rapid.
5. Barriers to interspecific crossings are fewer.	5. Barriers to interspecific crossings are more pronounced.

Biological Evolution

Biological evolution in cellular forms of life would have started when they originated on earth. According to natural selection the rate of appearance of new forms is linked to the life span. Microorganisms divide very fast because they have ability to multiply and become millions of individuals within hours. Suppose a colony of bacteria (Say A) is growing on a given medium. Due to ability to utilize a feed, variation developed in some individuals. It is due to change of medium composition. The individuals of that part of the population (Say B) can survive under the new conditions. In due course of time this different population outgrows the others and can form new species. If the same thing is to happen in a fish or fowl it would take million of years, because life cycles of these animals are in years. Under the new conditions fitness of population B is better than that of population A. Nature selects for fitness. Fitness is based on certain characteristics which are inherited. Thus there is genetic basis for getting selected and to evolve. In other words, some individuals are better adapted to survive in new environment as the **adaptive ability** is transmitted to next generation as *it has a genetic basis and is selected by nature*.

Branching descent and natural selection are the two basic points in Darwinian theory of evolution (Figures 7.39 and 7.48). Good example of branching descent is convergent evolution of Australian Marsupials and placental mammals. Types of natural selection on different traits, *i.e.*, (a) stabilising, (b) directional and (c) disruptive are examples of natural selection.

Mechanism of Evolution

Now the question arises that what is the origin of variation and how is species formed? Mendel also had mentioned about inheritable 'factors' influencing phenotype. Darwin could not mention these observations. Credit for this goes to **Hugo de Vries** who worked on **Evening primrose**. Hugo de Vries (1848–1935), a Dutch botanist, one of the independent rediscoverers of Mendelism, put forward his views regarding the formation of new species in 1901. He also met some of the objections found in Darwin's theory. According to him, new species are not formed by continuous variations but by sudden appearance of variations, which he named as **mutations**. Hugo de Vries stated that mutations are heritable and persist in successive generations.

Hugo de Vries believed that mutation causes evolution and not the minor heritable variations which was mentioned by Darwin. Mutations are random and directionless while Darwin's variations are small and directional. According to Darwin evolution is gradual while Hugo de Vries believed that mutation caused species formation and hence known as **saltation** (single step large mutation).

Hardy-Weinberg Principle

It was proposed by **G.H. Hardy**, an English mathematician and **W. Weinberg**, a German physician independently in 1908. It describes a theoretical situation in which a population is undergoing no evolutionary change. In fact, it defines the genetic structure of a non-evolving population.

Mutations introduce new genes into a species resulting a change in **gene frequencies**. Gene frequency is the frequency with which a particular allele occurs in a population. The term allele is employed for any two forms of a gene present on the same locus in the two homologous chromosomes. If certain conditions existed, gene frequencies are supposed to

remain fixed and even remain the same through generations. Thus HW Principle states that allele frequencies in a population are stable and is constant from generation to generation. The gene pool (total genes and their alleles in a population) remains constant. This is called **genetic equilibrium**.

Essential conditions of Hardy-Weinberg Principle. The Hardy's-Weinberg Principle explains the stability of population and species over a number of generations and is applicable only under the following conditions (Five factors affect the Hardy-Weinberg Principle).

1. **No Mutation.** Sudden appearance of variations are called mutations. There should not be either gene or chromosomal mutation.
2. **No Gene flow (Gene Migration).** Within the gene pool of a given breeding population there is a continual interchange of alleles between organisms. Gene flow refers to the movement of alleles from one population to another as a result of interbreeding between members of the two populations. The removal of alleles from one population or addition of alleles into another population is called gene flow or gene migration. *There must not be gene flow between the population.*
3. **No Genetic Drift.** Genetic drift is also known as "Sewell Wright Effect" (named after its discoverer). It is random in gene (allele) frequency. It occurs only by chance. It is non directional. Genetic drift can cause elimination of certain alleles or fixation of the other alleles in the population. Genetic drift refers to a change in the population of alleles in the gene pool. So genetic drift must not occur.
4. **No Genetic Recombination.** The alleles of parental linkage groups separate and new associations of alleles are formed in the gamete cells, this process is known as **genetic recombination**. Thus crossing over during meiosis is a major source of genetic variation within population. Offspring formed from these gametes showing 'new' combination of characteristics are called **recombinants**. There is no genetic recombination.
5. **No Natural Selection Pressure.** There must be no natural selection pressure with respect to the alleles in question.

According to Hardy-Weinberg Principle, *gene frequencies will remain constant if all above five conditions are met.*

Individual frequencies for example may be named p, q etc. In a diploid p and q represent the frequency of allele A and allele a. The frequency of AA individuals in a population is p^2 . This can be stated in another way, *i.e.*, the probability that an allele A with a frequency of p appears on both the chromosomes of a diploid individual is the product of the probabilities *i.e.*, p^2 . Similarly of aa is q^2 , of Aa is $2pq$. Thus $p^2 + 2pq + q^2 = 1$. This is a binomial expansion of $(p + q)^2$.

It is possible to calculate all allele and genotype frequencies using the expressions allele frequency $p + q = 1$, and genotype frequency $p^2 + 2pq + q^2 = 1$.

Constant gene frequencies over several generations indicate that evolution is not taking place. Changing gene frequencies would indicate that evolution is in progress. In other words, *evolution occurs when the genetic equilibrium is upset (evolution is a departure from Hardy-Weinberg Principle).*

Brief Account of Evolution

It is thought that about 2000 million years ago (mya*) the first cellular forms of life originated on earth. Some of these cells had pigments to capture solar energy and release

*Mya = Million ; Bya = Billion

oxygen by employing water as hydrogen donor in the process of photosynthesis. Prokaryotes originated in archaeozoic era. Slowly prokaryotes became eukaryotes. The fossils are scanty in this era.

Evolution of Plants. (i) Eukaryotes further diversified to form green algae and early invertebrates.

(ii) The first organisms that existed on land were plants.

(iii) Bryophytes were the first plants to colonise lands.

(iv) Fossils in good number are found from **palaeozoic era**. Middle palaeozoic is also called "age of algae". Late palaeozoic is called "age of ferns".

(v) All algal groups became established during **cambrian period**.

(vi) **First land plants (psilophytes)** originated in **ordovician period**. Marine algae were abundant in ordovician period.

(vii) Earliest spore-bearing plants were developed in **silurian period**. Origin of vascular plants (gymnosperms and angiosperms) took place in this period. It is also period of origin of ferns

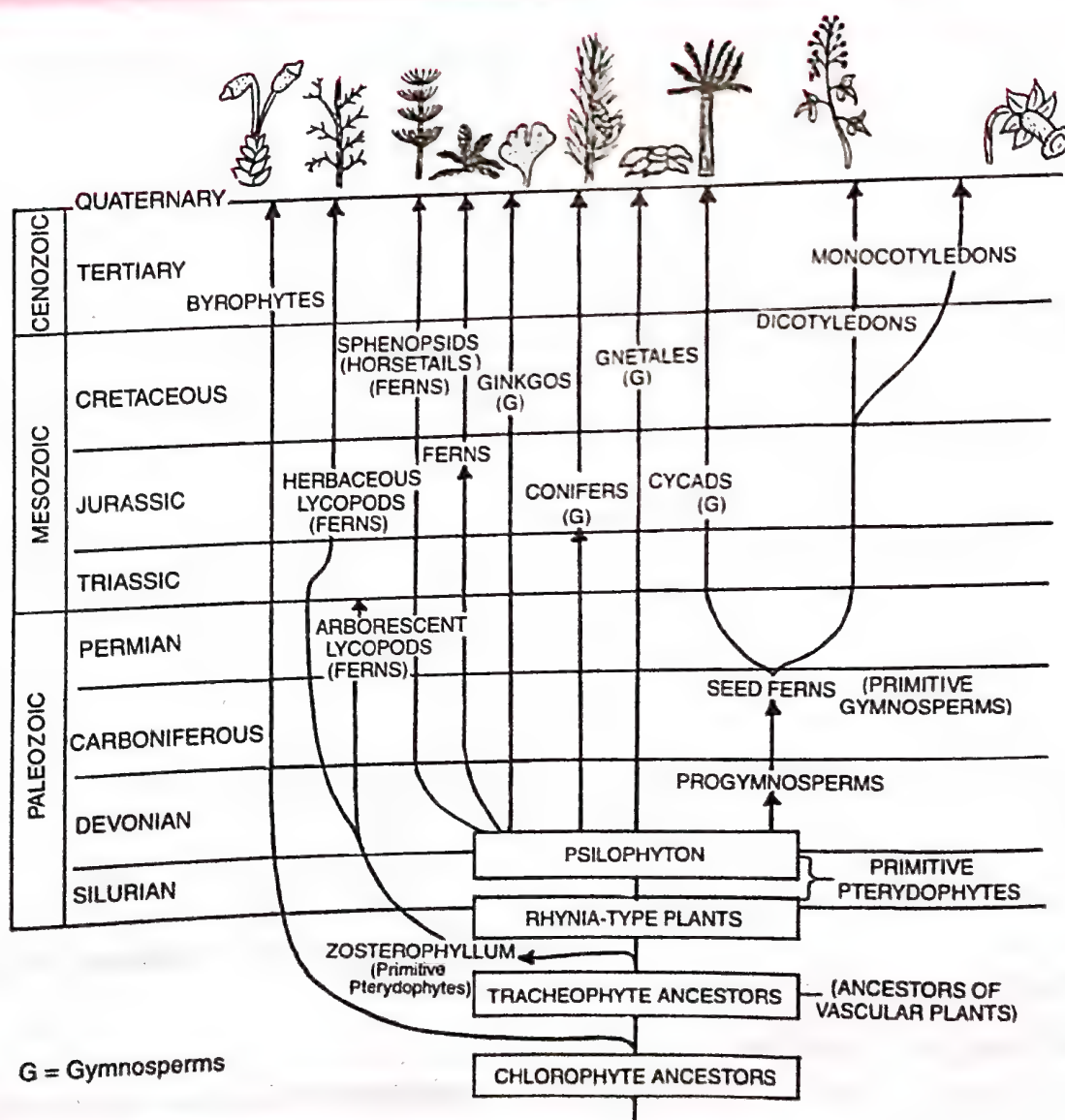


Fig. 7.52. A sketch of Evolution of Plants through geological periods.

(viii) Herbaceous lycopods (ferns) and aborescent lycopods (ferns) evolved from *Zosterophyllum* of palaeozoic era.

(ix) *Psilophyton* is the common ancestor for horsetails, ferns and gymnosperms.

(x) **Devonian**. Earliest mosses and ferns.

(xi) **Carboniferous** — Abundance of tree ferns forming coal forests. First seed plants appeared.

(xii) **Mesozoic era**. Also called age of gymnosperms.

(xiii) **Permian** — Origin of Conifers.

(xiv) **Triassic** — Abundance of ferns, cycads and conifers.

(xv) **Jurassic** — Age of cycads (they were in abundance). Origin of angiosperms also took place in this period.

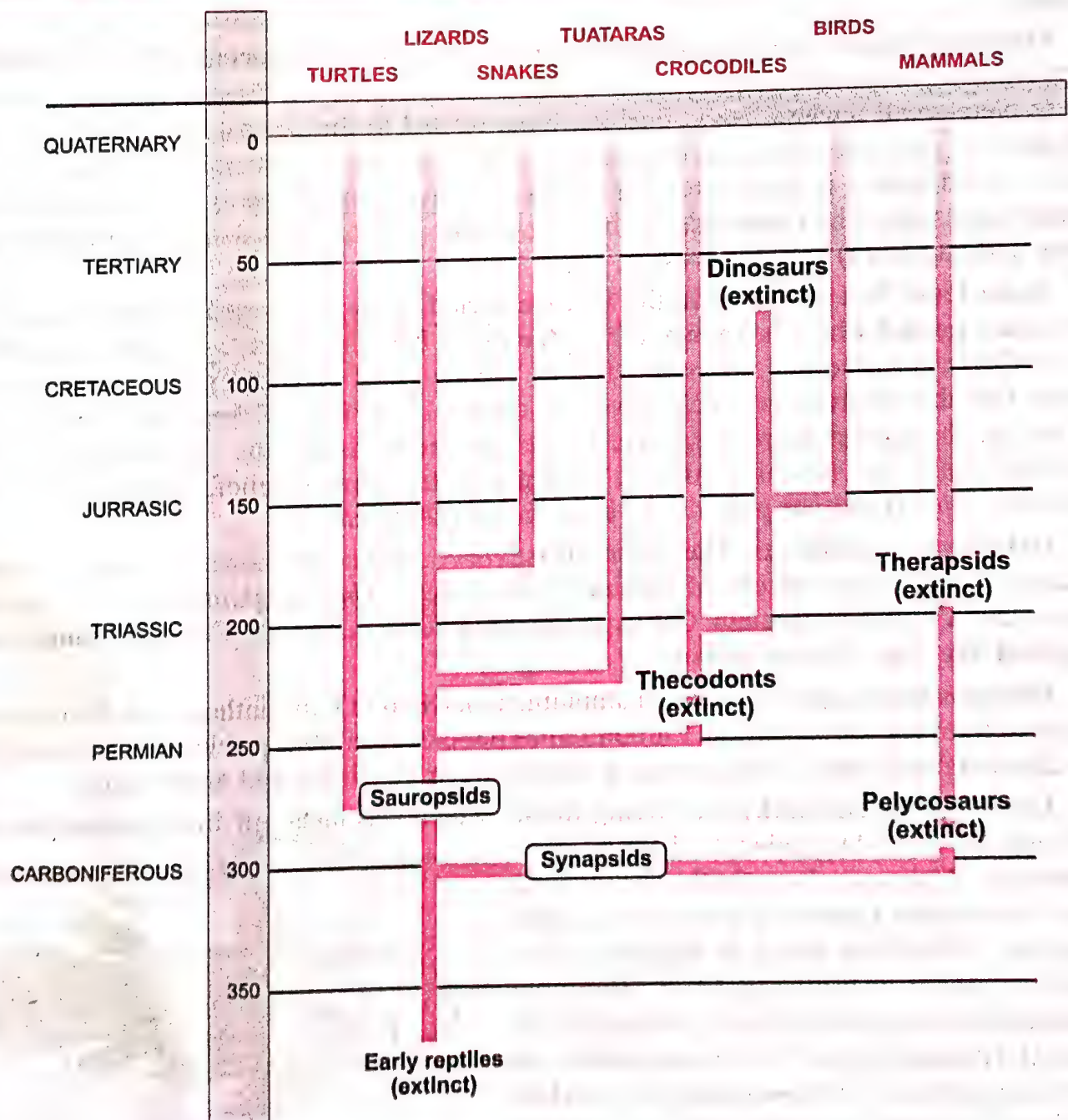


Fig. 7.53. Representative evolutionary history of vertebrates through geological periods.

- (xvi) Ferns and gymnosperms began to decline during **cretaceous period**. There was dominance of flowering plants.
- (xvii) Tertiary period is also called **age of angiosperms**. Quaternary period is similarly known as the **age of herbs**.
- (xviii) **Eocene** — Angiosperm dominance increases.
- (xix) **Oligocene** — Rise of monocots.
- (xx) **Miocene** — Adaptive radiation of angiosperms.
- (xxi) **Pliocene** — Adaptive radiation of flowering plants.
- (xxii) **Holocene** — Development and rise of herbs, decline of woody plants.

Evolution of Animals. There were plenty of plants when animals came to land. All invertebrates were established by the end of cambrian period. Ordovician period (500 mya) is considered to be age of invertebrates. Origin of vertebrates took place in ordovician periods.

Origin of Fishes. Origin of fishes took place in **ordovician period**. *The first fossils of vertebrates were found in the rocks of the ordovician period in the form of the ostracoderms.* These were small jawless, bony, fishlike forms related to the cyclostomes that lived some 480 million years ago. The scarcity of early vertebrate fossils is probably due to the fact that they evolved mainly in freshwater and did not have as much chance to become fossilized as marine forms did. The *Ostracoderms* became extinct but some *Cyclostomata* (modern lampreys and hagfishes) are still present.

Some fossil fish are found in the Silurian period, more are present in the succeeding **Devonian period** which is known as the **Age of Fishes**. The fossil ostracoderms probably evolved from unarmoured ancestors such as *Jamoytius*. They could not compete with the jawed fish that evolved in such diversity during Devonian and became extinct. Before extinction the ostracoderms gave rise to the first bony fishes, the placoderms, and the cartilaginous fishes (chondrichthyes). Contrary to the former belief, cartilaginous fishes (*Chondrichthyes*) did not give rise to bony fishes (*Osteichthyes*).

Origin of Amphibians. The earliest fossils of Amphibia are known as *Labyrinthodontia* because of the folded nature of dentine of their teeth. *They originated during Devonian period* and flourished through Carboniferous and Permian periods. **Carboniferous period is called the Age of Amphibians.**

Ichthyostega is a primitive fossil amphibian included in Labyrinthodontia. Its fossils are obtained from late Devonian and Carboniferous periods. It exhibits piscine as well as amphibian characteristics and is regarded as a link between the fishes and amphibians.

Latimeria (Coelacanth) is a "living fossil" which was taken off from the eastern coast of South Africa, on December 22, 1938 by some fishermen. Fishermen brought the specimen to Miss Courtenary Latimer, Curator of the local museum. When she failed to identify it, she sent its sketch to Professor J.L.B. Smith, an eminent Ichthyologist of Rhodes University College at Grahams town. He recognised it as surviving member of *Crossopterygii* (subclass of class *Osteichthyes*) and named it *Latimeria chalumnae* after the discoverer and locality. Its

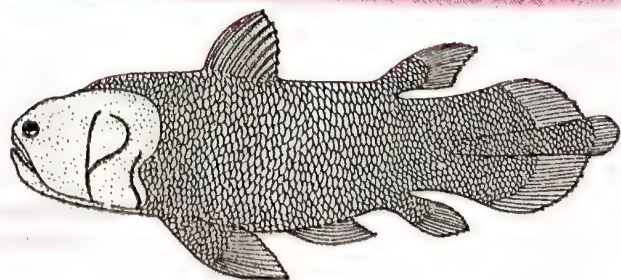


Fig. 7.54. *Latimeria*.

discovery is of special interest, because it is believed that crossopterygians (fleshy finned fish) were the ancestors of the first amphibians. *Latimeria* is believed to be the oldest amongst living fishes. It is a connecting link between fishes and amphibians (first tetrapods). There are no specimens of Coelacanth left with us. These animals evolved into the first amphibians that lived on both land and water. Thus they were ancestors of modern day frogs and salamanders.

Origin of Reptiles. *Reptiles originated* from some primitive labyrinthodont amphibians in the beginning of carboniferous period. They flourished through carboniferous and permian periods. It is important to note that we cannot point out a single ancestor of reptiles. Probably, they arose polyphyletically along a dozen or more independent lines.

During carboniferous period of late Palaeozoic era, some labyrinthodont amphibians gradually took on reptilian characters. These **earliest** reptiles are called the **stem reptiles**. They belong to the order **Cotylosauria** of the subclass **Anapsida**. The transition was so gradual that often it is difficult to decide whether some fossil skeletons are those of advanced amphibians or primitive reptiles.

Seymouria was one of the members of the cotylosauria, found in the Lower permian. It was lizard-like animal with a comparatively thick body, relatively small pointed head with dorsally placed nostrils, and a short tail. Structure of *Seymouria* was intermediate between the amphibians of that time and the early reptiles.

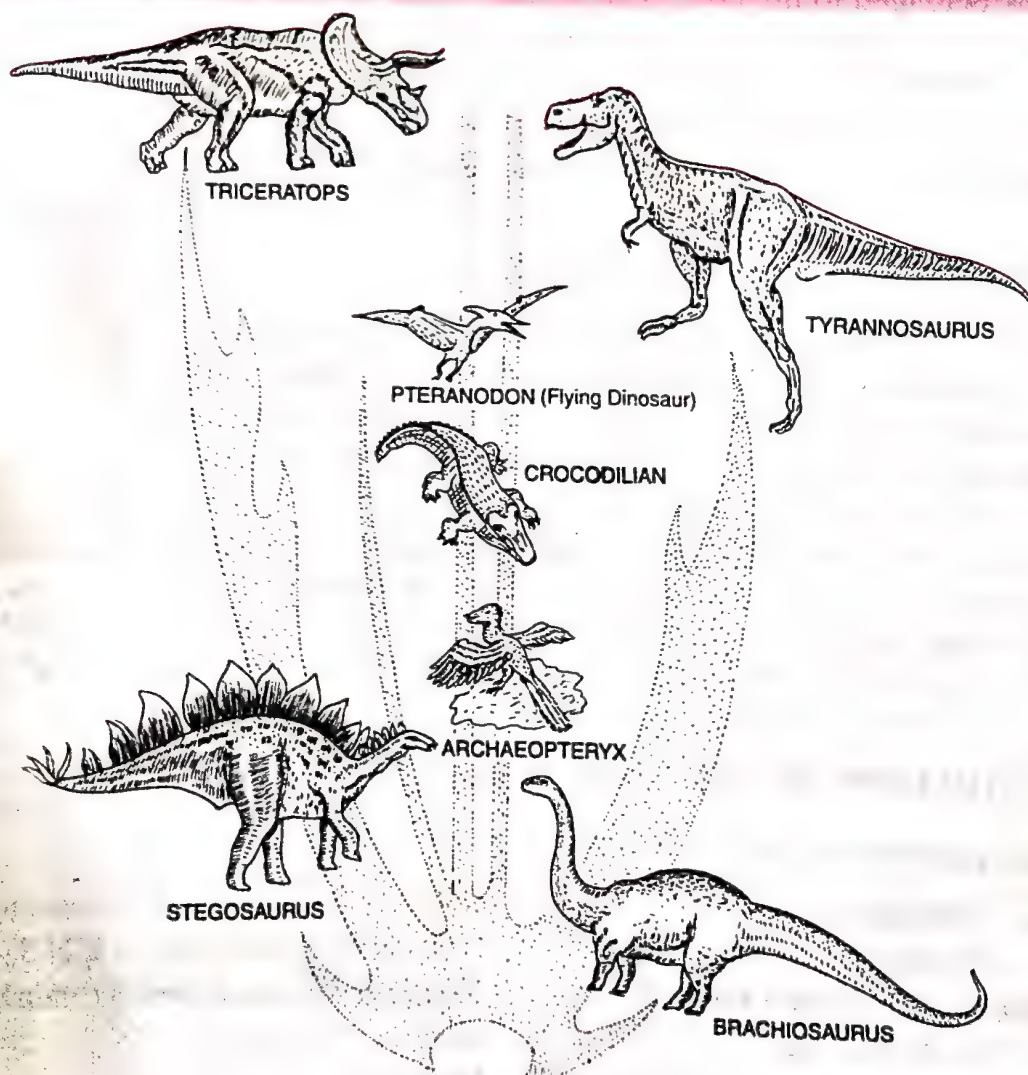


Fig. 7.55. A family tree of dinosaurs and their living modern day counterpart organisms like crocodiles and birds.

Dinosaurs originated in the Triassic period, dominated in Jurassic period and became extinct in cretaceous period. *Pteranodon* was flying dinosaur. *Tyrannosaurus* was giant carnivorous dinosaur. *Brachiosaurus* was biggest of them. Its weight was 50 tons. Dinosaurs originated in Triassic period of Mesozoic Era. **Jurassic period is called Age of Reptiles.**

Origin of Birds. Although, reptiles dominated the scene in Mesozoic era, many other important groups of organisms appeared. Birds evolved from the same bipedal thecodonts. *The first fossil birds found in the rocks of Jurassic period* belonged to genera *Archaeopteryx* and *Archaeornis*. It was about the size of a crow and possessed feathers and wings but had a long reptilian tail very much unlike the modern birds and a toothed beak. Fossils of *Hesperornis*, an aquatic diving bird, and *Ichthyornis*, a powerful flying bird, have been found from Cretaceous.

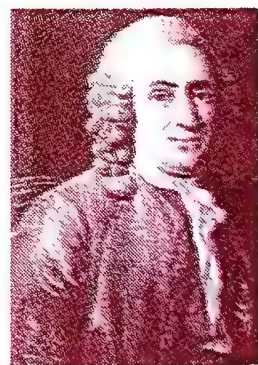
In fact the birds arose from the Archosaurian Diapsid reptiles. **Archosauria** is a subclass of Reptilia. The more usually accepted view today maintains that birds have a **monophyletic** (one line of descent) **origin**. It means all birds have evolved from a single ancestor, perhaps close to *Archaeopteryx*.

Origin of Mammals. *Origin of mammals took place in Triassic period.* It means dinosaurs and mammals originated in the same period. Long before the arrival of true mammals, one group of extinct reptiles, the **Synapsida** acquired several mammalian characteristics. They lived throughout the Permian and Triassic periods. The more mammals-like synapsids belonged to the order **Therapsida**. One of the more advanced carnivorous therapsids (suborder Theriodontia) was called *Cynognathus* (dog jaw). It lived during the early Triassic period. It was wolf sized and a mammal like reptile. It was one of the ancient reptilian ancestors of mammals who had characters of both reptiles and mammals.

Lycaenops was mammal-like reptile which is also considered a link between reptiles and mammals.

EARLY IDEAS ON HUMAN ANCESTRY

In 1863 T.A. Huxley made a scientific attempt to the problem of man's origin in his book "**Man's Place in Nature**" and established that our closest relatives are apes. Later, in 1871 Charles Darwin published his idea about man's ancestry in the book "**The Descent of Man**". He did not know any human fossil. His ideas were based entirely on the evidences from living men and primates. Darwin suggested that man, apes and monkeys have a common ancestor. **Carolus Linnaeus**, the **Father of Taxonomy**, placed man among the monkeys and apes. Linnaeus gave scientific name, the *Homo sapiens*, to man which means "man who is wise". Here, the word 'man' is used for both man and woman.



Carolus Linnaeus
1707–1778

PLACE OF HUMANS IN THE ANIMAL KINGDOM

Taxonomic position of Modern Humans is given below.

Kingdom — Animalia	—	Intake of complex food, defaecation
Phylum — Chordata	—	Notochord, Dorsal Hollow C.N.S.
Sub-phylum — Vertebrata (Craniata)	—	Vertebral column, Cranium (brain box)
Section — Gnathostomata	—	Jaws
Superclass — Tetrapoda	—	Four limbs
Class — Mammalia	—	Mammary glands, Hair, Pinna

Subclass — Theria	—	Viviparous
Infra class — Eutheria	—	True placenta
Order — Primates	—	Nails over the Digits
Sub order — Anthropoidea	—	Facial Muscles for emotional expression
Family — Hominidae	—	Erect posture Bipedal locomotion
Genus — <i>Homo</i>	—	Man
Species — <i>sapiens</i>	—	Wise
Subspecies — <i>sapiens</i>		

Homo sapiens means "man who is wise"

Primates include prosimians (e.g., lemur, loris and tarsier) and simians, (e.g., monkeys, apes and man).
Anthropoids (simians) include monkeys, apes and man.
Hominoids include tailless primates (e.g., apes and man)
Hominids include *Homo* group.
Parapithecus was discovered from the oligocene. This fossil is believed to represent the ancestors of today's old world monkeys, apes and humans.

SIMILARITIES BETWEEN APES AND MAN

A close relationship of apes with man is revealed by the following characters.

- (i) Absence of a tail.
- (ii) Relatively larger head, and longer neck and limbs.
- (iii) Broadened chest due to flattening of sternum.
- (iv) Smaller lumbar region due to reduced number of lumbar vertebrae.
- (v) Relatively larger brain and cranial cavity; efficient memory.
- (vi) Prominent browridges above the eyes.

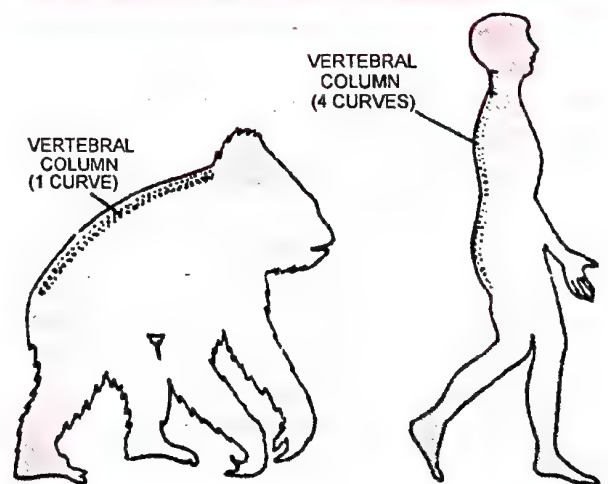


Fig. 7.56. Backbone curves in ape and man.

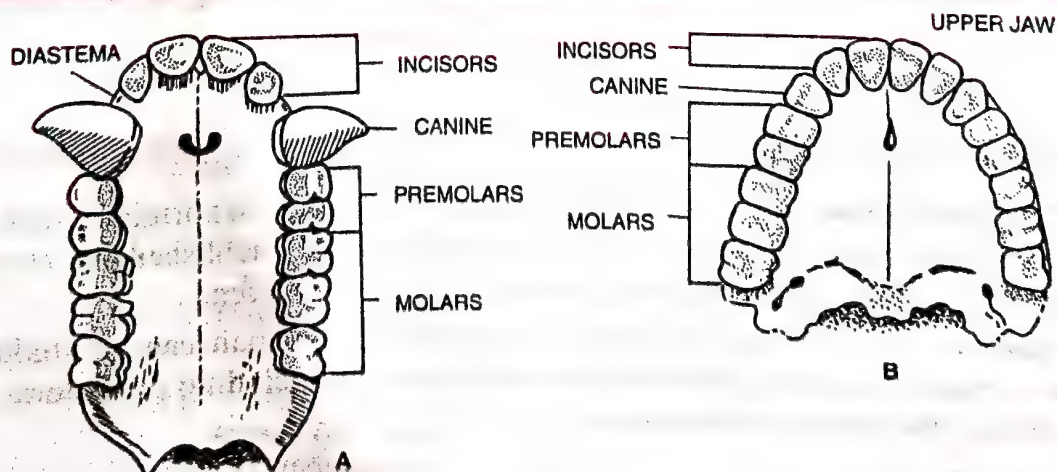


Fig. 7.57. The jaws and teeth of ape and human. A, Gorilla. B, Living modern human.

(viii) Capability of communication by vocal means (sounds).

(ix) Highly developed facial musculature for expression of rage, surprise, pleasure and laughter by facial gestures.

(x) Tendency to live in pairs as couples; menstruation in females.

On basis of such a close resemblance between apes and man, it has been presumed that modern apes and man are 'cousins' descended from common ancestors.

Differences between Ape and Man

Ape	Man
1. Less erect posture.	1. Fully erect posture.
2. Brow ridges are very prominent.	2. Brow ridges are not so prominent.
3. It has a well marked chin.	3. It has a prominent chin.
4. It is herbivorous.	4. It is omnivorous.
5. Locomotion is quadrupedal.	5. Locomotion is bipedal.
6. Jaws are protruded.	6. Jaws are not protruded.
7. Incisor and canine teeth are large. Canines are projecting.	7. Incisor and Canine teeth are comparatively small. Canines are not projecting.
8. There is small diastema between incisors and canines.	8. There is no diastema.
9. Anterior premolar in the lower jaw is strong and pointed.	9. Anterior premolar in the lower jaw is small and bicuspid.
10. Brain box (cranium) is of small size.	10. Brain box is of large size.
11. Neck is very short.	11. Neck is comparatively long.
12. Neck muscles allow very little movement of head on the neck.	12. Neck muscles allow more movement of head on neck.
13. Arms are longer than the legs.	13. Legs are longer than the arms.
14. Pelvic girdle is narrow and elongated.	14. Pelvic girdle is broad and flattened.
15. Both pollex (thumb) and hallux (great toe) are opposable.	15. Pollex is opposable, hallux is not oppoable.
16. Vertebral column has one curve.	16. Vertebral column has four curves.
17. Cranial capacity is under 450 cc.	17. Cranial capacity (average) is about 1450 cc.
18. Body covered with long, coarse hair.	18. Body has short sparse hair.
19. The sole of the foot does not lie flat on the ground while walking.	19. The sole of the foot lies flat on the ground while walking.
20. It leads chiefly arboreal life.	20. It leads terrestrial life.
21. Ape is not able to make and employ tools, use of spoken and written language to communicate.	21. Man has ability to make and employ tools, use of spoken and written language to communicate.

ORIGIN AND EVOLUTION OF MAN

Place of origin of man. The fossil evidence clearly indicates that origin of man occurred in Central Asia, China, Java and India (Shivalik Hills). It has been established that *Dryopithecus* is one of the oldest fossil which in turn evolved into apes and men.

For the sake of convenience, the origin and evolution of man can be studied in the following three major headings : prior to ape men, ape men including prehistoric man and true men including the living modern man.

Morphological Changes involved in Evolution of Man

The following main morphological changes occurred in the ancestors of modern man.

(1) Narrowing and elevation of nose. (2) Formation of chin. (3) Reduction of brow ridges. (4) Flattening of face. (5) Reduction in body hairs. (6) Development of curves in the vertebral column for erect posture. (7) Formation of bowl like pelvic girdle with broad ilia (pl. of ilium) in support of viscera. (8) Increase in height. (9) Attainment of erect posture and bipedal locomotion. (10) Enlargement and rounding of cranium. (11) Increase in brain size and intelligence. (12) Broadening of forehead and with vertical elevation.

The origin and evolution of man can be studied in the following three major headings. A. Prior to Ape Men, B. Ape Men including Prehistoric Men and C. True Men including the Living Modern Man.

A. Prior to Ape men

1. **Dryopithecus Discovery.** The fossil of *Dryopithecus africanus* was discovered from Miocene rocks of Africa and Europe. It lived about 15 million years ago.

Characteristics. It was more ape-like and was hairy and walked like gorilla and chimpanzee. It was arboreal, knuckle-walker and ate soft fruits and leaves. *Dryopithecus africanus* is regarded a *common ancestor of man and apes* (gibbons, orangutan, chimpanzee and gorilla).

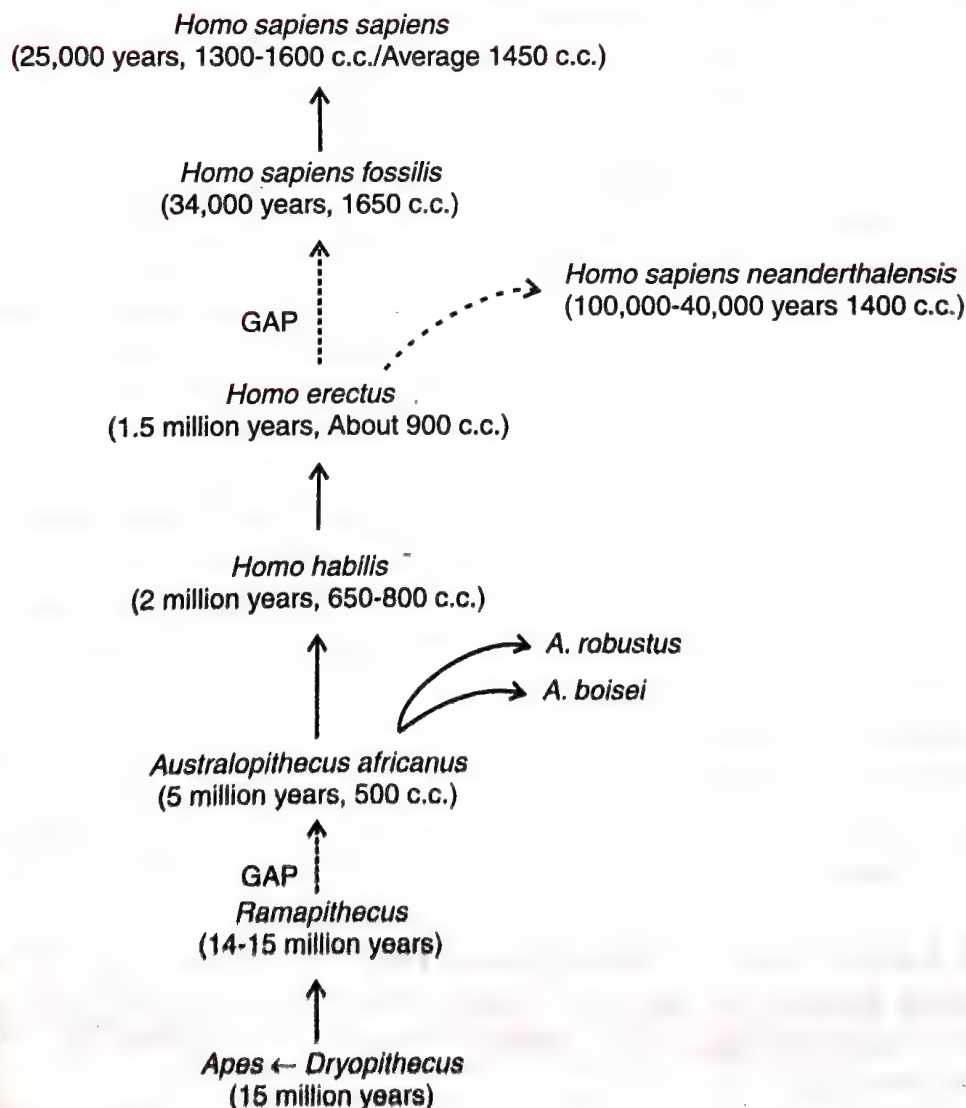


Fig. 7.58. Schematic representation of Evolution of Man. Age and cranial capacity are also given.

2. Ramapithecus. Discovery. It has been established that in late Miocene epoch *Dryopithecus* gave rise to *Ramapithecus* ('Rama' = The hero of Indian legend, *pithecus* = ape) which was on the direct line of human evolution, *Ramapithecus* survived from late Miocene to Pliocene. Thus he appeared about 14–15 million years ago. Fossil of *Ramapithecus* was discovered by Edward Lewis (1932) from Pliocene rocks of Shivalik Hills of India.

Characteristics. It was more man-like and was hairy and walked like gorilla and chimpanzee. Its small canines and large molars suggest that *Ramapithecus* ate hard nuts and seeds like modern man.

Kenyapithecus wickeri was discovered by L.S.B. Leakey (1962) from Pliocene rocks of Kenya (Africa). It was similar to *Ramapithecus*. But *Ramapithecus* was older than *Kenyapithecus*.

There is a gap* of about 9 to 10 million years in *Ramapithecus* and *Australopithecus* (to be described).

B. Ape Men including Prehistoric Men

1. Australopithecus (First ape man). *Australopithecus*.

Discovery. Raymond Dart (1924), South African anthropologist, discovered the fossil of *Australopithecus africanus* (African Ape man) from Pliocene rocks near Tuang in Africa. He appeared about 5 million years ago. Actually skull discovered by Dart was of 5–6 year old baby so it is also called 'Tuang child'. Some fossils of *A. africanus* were also discovered from Pleistocene epoch.

Characteristics. *Australopithecines* probably lived in East African grass lands. *Australopithecus africanus* was about 1.5 metres high and had human as well as ape characters. It was with bipedal locomotion, omnivorous diet but essentially ate fruit and had erect posture. It had human like teeth but it had more of an ape brain than a human brain. Its brain capacity was about 500 c.c. similar to that of an ape. Brow ridges projected over the eyes. It did not have chin. *Australopithecus africanus* gave rise to *Homo habilis*.

Australopithecus africanus also gave rise to man-like apes called *Australopithecus robustus* and *Australopithecus boisei* along a separate line that ended blindly (They did not give rise to any other creatures).

In 1981 Donald Johanson, found a 3.2 million years old skeleton of a female human ancestor. He nicknamed it Lucy. Lucy's scientific name is *Australopithecus afarensis*.

Six species of *Australopithecus* are known. These are *A. africanus* (African Ape man, Southern Ape or Tuang baby), *A. afarensis* (Lucy), *A. ramidus*, *A. aethiopicus*, *A. robustus* and *A. boisei*.

2. Homo habilis (Able or Skillful man, The tool maker, or 'Handy man').
Discovery. L.S.B. Leakey and his wife Mary Leakey (1960) discovered the fossils of *Homo habilis* from pleistocene rocks of Olduvai Gorge in East Africa. He lived in Africa about 2 million years ago.

The early human stock gave rise to

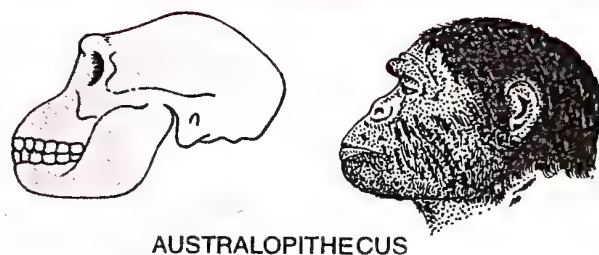
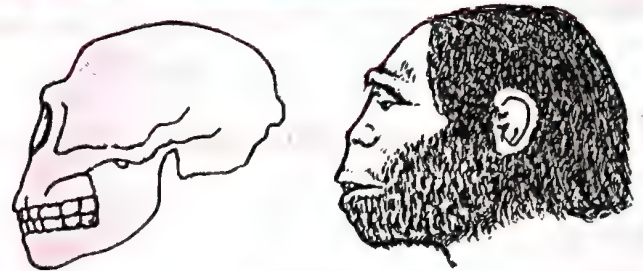


Fig. 7.59. Skull and reconstructed head.

* This gap has not so far yielded any useful hominid fossils

Characteristics. It was about 1.2 to 1.5 metres tall. It had bipedal locomotion, moved erect and was omnivorous. It probably did not eat meat. Its brain capacity was between 650-800 c.c. *Homo habilis* (*habilis* = mentally able or skillful) was the first tool maker and used tools of chipped stones extensively. It is also called handy man because heaps of tools found with these fossils included sharpened stones which indicate that *Homo habilis* was capable of 'making tools'.



HOMO HABILIS

Fig. 7.60. Skull and reconstructed head.

3. ***Homo erectus* (Erect man).** *Homo erectus* appeared about 1.5 million years ago in middle pleistocene. *H. erectus* evolved from *Homo habilis*. He was about 1.5-1.8 metres tall. *Homo erectus* males were probably larger than females. He had erect posture. He had protruding jaws, projecting brow ridges and small canines and large molar teeth. The cranial capacity was about 900 cc. He was omnivorous. He probably ate meat. He made more elaborate tools of stones and bones, hunted big game and perhaps knew use of fire.



HOMO ERECTUS

Fig. 7.61. Skull and reconstructed head.

Homo erectus includes three fossils : Java Ape-man, Peking man and Heidelberg man.

(i) **Java Ape man. Discovery.** In 1891, **Eugene Dubois** discovered a fossil from pleistocene rocks in central Java (Island of Indonesia). Eugene Dubois named it as *Pithecanthropus erectus*. *Pithecanthropus* means 'ape man'. Mayer in 1950 assigned it as *Homo erectus*.

Characteristics. Body 1.65 to 1.75 metres tall. Perhaps he was the first prehistoric man to make use of fire for hunting, defence and cooking.

(ii) **Peking Man. Discovery.** W.C. Pei (1924) discovered the fossils of Peking man from the lime stone caves of Choukoutien near Peking (Beijing- capital of China was formerly known as Peking) and named them *Sinanthropus*. Davidson Black (1927) named it *Sinanthropus pekinensis*. Mayer (1950) renamed it as *Homo erectus pekinensis* (a subspecies). The pleistocene rocks from which fossils of Peking man were excavated.

Characteristics. Placing Java ape man and Peking man as subspecies of *Homo erectus* has a sound basis, because of close similarities between these. The body structure was quite similar in both. Being about 1.55 to 1.60 metres tall, Peking man was slightly shorter and a little lighter and weaker. The only noticeable difference of Peking man from Java ape man was its larger cranial capacity. There is a clear evidence of use of fire by it. It has been confirmed that both Java and Peking men used to live in caves in small groups or tribes. The tools of Peking man were relatively more sophisticated.

(iii) **Heidelberg man. Discovery.** In 1908 one of the most perfect fossil jaws belonging to middle Pleistocene was found by workmen working near Heidelberg, Germany. It was shown to **Otto Schoetensack**, who gets the credit for its discovery. It was named *Homo erectus heidelbergensis*.

Characteristics. It had lower jaw with all the teeth. The teeth were human like. The massive jaw was ape-like. He used the tools and fire.

There is another gap of about 50,000 years in the fossil record of evolution of man.

C. True men including the Living Modern Man

1. **Neanderthal Man** (*Homo sapiens neanderthalensis*). **Discovery.** Fossils of Neanderthal man were first obtained from Neander Valley in Germany from the late Pleistocene epoch by C. Fuhlrott (1856). Later many other fossils were excavated in various countries by different palaeontologists.

Characteristics. He had slightly **prognathous face** (having a forward projecting face and jaws). Neanderthals walked upright, as we do, and had low brows, receding jaws, and high domed heads. If there was anything truly different about them, it was that they were much stockier than we are. Their cranial capacity was 1400 cubic centimetres. They lived in near east and central Asia between 1,00,000–40,000 years back.

Neanderthals were the legendary cave dwellers. They have been portrayed as having heavy brow ridges and humped backs.

Neanderthals were adapted to a cold environment. They encountered the succession of glaciers that passed over most of the northern temperate regions of the world. They were not only skilled hunters but true predators, a specialization that did not occur among hominids before or after them. The neanderthals were omnivorous (meat as main diet) and cannibals. They fashioned the skin into clothing to protect themselves against the harsh climate. Natural caves became campsites that were illuminated and heated by fire. It is believed that he buried his dead with flowers and tools. He may had a religion.

It is usually considered that *Homo sapiens neanderthalensis* did not evolve into *Homo sapiens*.

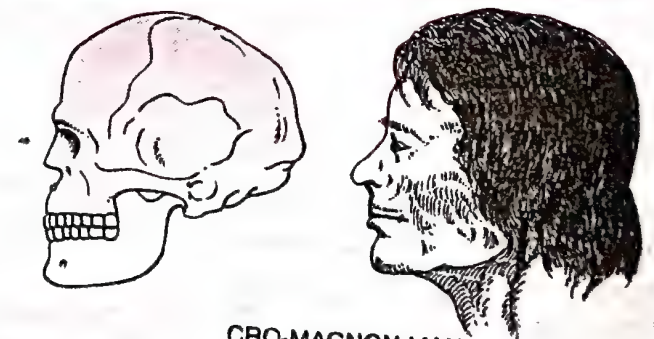
2. **Cro-Magnon man** (*Homo sapiens fossilis*). **Discovery.** It has been known as Cro-Magnon man, because its fossils were first discovered in 1868 from Cro-Magnon rocks of France by MacGregor. Cro-Magnon man emerged about 34000 years ago in Holocene epoch. Thus, it is regarded as most recent ancestor of today's man.

Characteristics. The Cro-Magnon man had, like us, about 1.8 metres tall, well-built body. Its face was perfectly **orthognathous** (Jaws do not project forward) with an arrow, elevated nose, broad and arched forehead, moderate brow ridges, strong jaws with man-like dentition, and a well developed chin. Its cranial capacity was, however, somewhat more than ours, being about 1650 cc. It is, therefore, believed that Cro Magnon man was somewhat more intelligent and cultured than the man of today. It could walk and run faster and lived in families in caves.



NEANDERTHAL MAN

Fig. 7.62. Skull and reconstructed head.



CRO-MAGNON MAN

Fig. 7.63. Skull and reconstructed head.

It made excellent tools and even ornaments, not only of stones and bones, but also of elephant tusks. Its tools included spears, bows and arrows, as he was omnivorous. Use of the skin clothes by this man is also confirmed. A number of cave paintings done by Cro-Magnon man have been discovered. It became extinct about 10,000–11,000 years ago.

The Cro-Magnon man was the direct ancestor of the living modern man.

3. The Living Modern Man (*Homo sapiens sapiens*) Discovery. Further evolution of man after Cro-Magnon involves the evolution of culture rather than that of anatomy. *Homo sapiens sapiens* appeared about 25000 years ago in Holocene epoch and started spreading all over the world about 10,000 years ago.

Characteristics. Morphologically, the transition is marked merely by a slight raising of skull cap, thinning of skull bones, a slight reduction in cranial capacity (1300–1600 c.c. average about 1450 c.c.), and formation of four curves in the vertebral column.

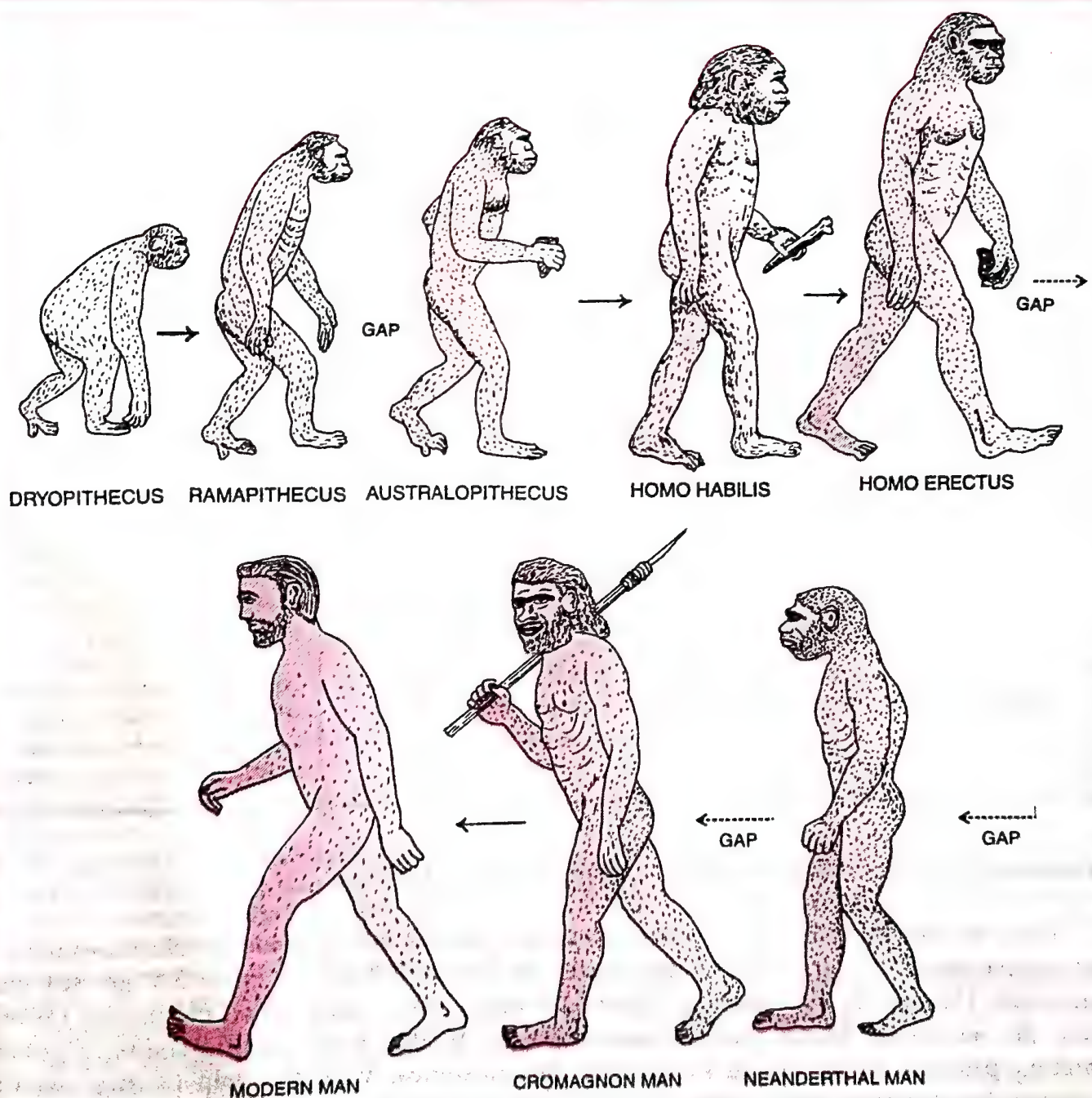


Fig. 7.64. Reconstruction of evolutionary stages of man.

It is believed that man of today first appeared in the region around Caspian and Mediterranean seas. From there its members migrated all over the world.

Pre-historic cave art developed about 18,000 years ago. Agriculture started around 10,000 years back.

Summary of human phylogeny				
Genus	Age of appearance/ million years ago	Brain capacity/cm ³	Diet	Significance
1. <i>Dryopithecus</i> (earliest fossil ape)	15 (Miocene)	?	Soft fruit, leaves	Was more ape-like. Arms and legs of equal size
2. <i>Ramapithecus</i> (Earliest hominid fossil)	14-15 (Miocene)	?	Seeds nuts	Was more man-like, ground dwellers
3. <i>Australopithecus africanus</i> (Tung child)	5 (Pliocene)	500	Omnivorous	Brow ridges projected over the eyes. It did not have chin.
4. <i>Homo habilis</i> (The tool maker, handy man)	2.0 (Pleistocene)	650-800	Probably did not eat meat	Earliest stone tools, major increase in brain size foreshadowing social attributes
5. <i>Homo erectus</i> (The erect man)	1.5 (Pleistocene)	900	Probably ate meat	Beginning of cultural evolution, used stone and bone tools, cooperative hunting used fire.
6. <i>Homo sapiens neanderthalensis</i> (Neanderthal man)	100,000 to 40,000 yrs. (Pleistocene)	1400	Omnivorous and Cannibal	Cave dweller used hides as clothes, buried the dead
7. <i>Homo sapiens fossilis</i> (Cro-Magnon man)	34000 yrs. (Holocene)	1650	Omnivorous	Strong jaws with teeth close together, wisdom teeth, cave-dweller, paintings and carvings in caves, had art and culture
8. <i>Homo sapiens sapiens</i> (Living modern man)	25000 yrs. (Holocene)	1300-1600 (Average 1450)	Omnivorous	Backbone with 4 curves; most intelligent; has art, culture, language, speech; cultivates plants; domesticates animals.

Homology in chromosomes of Man and Great Apes

Each human somatic cell contains 46 chromosomes out of these 46 chromosomes, 44 are autosomes and 2 are sex chromosomes. In female XX and in male XY are sex chromosomes. Human chromosomes are normally taken from white blood corpuscles (WBCs) from the peripheral blood. The chromosomes are treated with specific stains to produce banding patterns characteristic to specific chromosomes. With the help of these banding patterns the structure of the chromosomes can be studied.

Each somatic cell of gorilla, chimpanzee and orangutan has 48 chromosomes. A com-

parative study of the banded chromosomes of man and the great apes has also been done. It has also been observed that the banding pattern of individual human chromosomes is very similar to the banding pattern of corresponding chromosomes in apes. The banding pattern of human chromosome numbers 3 and 6 are compared (Fig. 7.65) with those of particular autosomes in the chimpanzee. It shows a common origin for man and chimpanzee.

Evidences for common Ancestry of Great Apes & Man

1. **Chromosomal evidence.** Already explained.
2. **Evidence from Blood Proteins.** It has been proved by the blood protein tests that man is most closely related to great apes (Chimpanzee and Gorilla) and next closest, in order, are the old world monkeys, the new world monkeys and tarsiers.
3. **Evidence from Blood Groups.** In humans four blood groups A, B, AB and O occur. The blood groups A and B are found in apes but not in monkeys. This indicates that human beings are more closely related to apes than to monkeys.
4. **Evidence from Haemoglobin.** There is 99 per cent homology in haemoglobin of man and gorilla. This suggests that the two are closely related.



Fig. 7.65. Diagrammatic representation of banding pattern in chromosomes number 3 and 6 of man and chimpanzee.

A, represents human chromosome. B, represents chromosome of chimpanzee.

ADDITIONAL INFORMATION

- **J.B.S. Haldane** was born on 5th December, 1892 in England. He migrated to India in July 1957 and settled in Bhubaneswar, Orissa. He died on 1st December 1964. He was biologist, biochemist and geneticist.
- **Exobiology:** Study of possible life outside the earth.
- **Progenote.** It is considered that it was an early single-celled common ancestor of archaeobacteria, eubacteria and eukaryotes. It indicates that there is no present day bacterial type which can be regarded as an ancestor of eukaryotes.
- **Anthropology.** Study of origin and development of humans in all their physical, social and cultural relationships.
- **Anthropobiology.** Study of the biological relationship of the human race.
- The word 'Dinosaur' was invented by Sir **Richard Owen** more than a century ago to designate certain large terrible fossil reptiles.
- **Synapsid reptiles** were mammal-like that gave rise to mammals. They had a single temporal fossa on the lateral side of skull and heterodont teeth. All synapsid reptiles are extinct.
- **G.J. Romanes** (1848–94) coined the term 'Neo-Darwinism' as well as the word 'ultra-Darwinism'.
- **Dollo's Law.** It states that evolution is irreversible. This law was proposed by L. Dollo in 1893.
- **Cope's Law.** It states that there is a tendency for animals to increase in size during the long course of evolution.

- **Bergman's Law.** It states that warm blooded animals, species living in cold climates tend to be larger than related species living in hot climates.
- **Allen's Law.** It states, animals that live in very cold climates, their extremities such as ears, tails, etc. become progressively smaller.
- **Gause's Law** (Gause, 1934) or the **Competitive Exclusion Principle** (Hardin, 1960). It states that two species having the same ecological requirements cannot continue to occupy indefinitely the same habitat.
- **Gloger's Rule.** It states that among warm blooded animals those living in warm and moisture climates develop more melanin pigment (darker than animals in cold, dry climates) whereas forms in dry, hot climates have more yellow and red pigment.
- **Jordan's Rule.** It states that fishes inhabiting water of low temperature tend to have more vertebrae than those of warmer waters. It has been observed that cold water forms of many species are frequently larger than the individuals from warmer waters.
- **The Ancon Sheep.** In Seth Wright's farm in Massachusetts, America, a normal sheep gave birth to a ram (male sheep) with very short and curved legs in 1791. By artificial breeding from this ram, Seth Wright raised a different variety of sheep called Ancon Sheep, (very short legged sheep). After several generations, this character suddenly disappeared. Formation and disappearance of Ancon sheep is good example of mutations (discontinuous variations).
- Main theories proposed by Charles Darwin are (i) **Natural Selection Theory** (ii) **Sexual Selection Theory** (iii) **Artificial Selection Theory** (iv) **Theory of Pangenesis.**
- **Mimicry.** It is a kind of adaptation. The term mimicry was introduced in biology by Bates (1862). It is defined as "the resemblance of one organism to another or to any natural object for the purpose of concealment, protection or for some other advantage. The organism which exhibits mimicry is called a **mimic**. The organism or object which is mimicked or imitated is called a **model**."
- **Batesian Mimicry.** It is a form of mimicry in which an edible species resembles an inedible one, e.g., Viceroy butterfly (edible) resembles monarch butterfly (inedible).
- **Mullerian Mimicry.** When two or more inedible or unpalatable species resemble each other the mimicry is termed Mullerian mimicry, e.g., honeybee, wasp, etc.
- Study of origin and structure of earth is called **geology** (Gr. *geo*— earth, *logos*— study).
- **Quantum Evolution.** It is a rapid evolution of a number of new taxa (organisms comprising a particular taxonomic entity) in a short span of time probably due to large scale environmental changes, e.g., development of land plants, wingless insects and scorpions.
- **Coevolution.** Evolution in two or more species of adaptations caused by the selection pressures each imposes on the other. Most host/parasite predator/prey, cleaner/cleaned relationships, etc., are likely to involve co-evolution.



Fig. 7.66. Representation of course of Wallace's line and Weber's line.

- **The Wallace's Line.** It is an imaginary line drawn by Wallace. It runs between **Philippines** and **Moluccas** in north, between **Borneo** and **Celebes** south-west and between **Bali** and **Lombok** south-ward.
- **Weber's Line.** Some years after the Wallace's line was drawn, **Weber** drew another line more eastwards separating **Moluccas** from **Celebes** on the north limit and **Kei** island from **Timor**.
- **Wallacea.** It is a transitional area between Wallace's line and Weber's line in which some of the animals of both the regions are found. Thus the islands i.e., **Celebes**, **Flores** and **Lombok** lying between the two lines, are not geologically part of Oriental region nor part of Australian region.
- There are two schools of zoogeographers, one prefers Wallace's line where as other approves of Weber's line for separating Oriental and Australian regions (realms).
- **Clines.** A species exhibiting a gradual change in phenotypic characteristics throughout its geographical range is referred to as a **cline**. More than one cline may be exhibited by a species and they may run in opposite directions.
- **Biopolesis.** The formation of living matter from nonliving material, especially in evolution.
- **Cladogenesis.** Multiplicative speciation is called cladogenesis.
- **Anagenesis.** Replacement of one species by another without an increase in the number of its own species is called **anagenesis**. It is also called **phyletic speciation**. Example *Eohippus* evolved into *Mesohippus* while itself became extinct.
- **Atlantic Man.** Its fossils were discovered in **Algeria, Africa** in 1955.
- **Rhodesian Man** (*Homo rhodesiensis*). Its remains were found from cave at **Broken Hills** in **Rhodesia, South Africa** in 1921.
- **Zinjanthropus**, "The olduvain toolmaker" was discovered by **Mary Leakey and L.S.B. Leakey** in 1959 in the **Zinj** area of **olduvai Gorge** of **Tanzania**.
- **Solo Man** (*Homo soloensis*). Its fossils were found on the banks of the **Solo river** in **Java** in 1936.
- **Piltown Man.** It was discovered at **Piltown, England** in 1912 but exposed in 1954 as a hoax.
- **Paranthropus.** It was discovered by **Robert Broom** in **South Africa** in 1938.
- Most primitive ape is **gibbon** and most developed ape is **gorilla**.
- *Hylobates hoolock* (the gibbon) is the only ape, found in **India** (forests of **Assam**).
- **Erasmus Darwin** (1731-1802), the grandfather of **Charles Darwin** gave the first clear statement of the inheritance of acquired characteristics, according to which the effects produced by the environment on the organisms are transmitted to the offspring. The theory was elaborated by **Lamarck** in the year 1809.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. Explain antibiotic resistance observed in bacteria in light of Darwinian selection theory.
✓ When a bacterial population faces a particular antibiotic which is sensitive to it, die. Few bacteria, having mutations which make them resistant to the antibiotic, survive. Such resistant bacteria multiply quickly because the competing bacteria have died and entire population becomes resistant.
2. Find out from newspapers and popular science articles any new fossil discoveries or controversies about evolution.
✓ Following are few new fossil discoveries or controversies about evolution found from newspaper and popular science articles.
 - (i) Fossil of dinosaurs reveal evolution of reptiles in Jurassic period and evolution of birds and mammals.
 - (ii) Recently fossils of shark-toothed reptiles from Sahara desert have been discovered.
 - (iii) Fossil of *Archaeopteryx*.
3. Attempt giving a clear definition of the term species.
✓ Biological species is defined as a potentially interbreeding group of individuals that are reproductively isolated from any other species.

4. Try to trace the various components of human evolution (hint : brain size and function, skeletal structure, dietary preference etc.)

✓ **Brain Size.** It increased gradually along with evolution. The brain capacity of *Australopithecus africanus* - 500C, *Homo habilis* - 700 CC, *Homo erectus* - 800 -1300 CC, *Homo sapiens sapiens* - 1450 CC

Skeletal Structure. (i) *Dryopithecus* — ape-like, without browridges, semierect posture, prognathus (having a projecting jaw). (ii) *Ramapithecus* — Jaws and teeth like humans (small canines and large molars), prognathous, walked on legs. (iii) *Australopithecus africanus* — Erect posture, human like teeth, without chin, with browridges, prognathus. (iv) *Homo habilis* — Moved erect, teeth human like, with browridges, walked nearly erect slightly prognathous. (v) *Homo erectus* — Erect posture, prognathous, projecting browridges, small canines and large molar teeth, small chin. (iv) *Homo sapiens sapiens* — Four curves in the vertebral column, face orthognathous (face without projecting jaw), forehead broad, chin well developed, walked on sole.

Dietary Preference. *Dryopithecus* — herbivorous, *Ramapithecus* — herbivorous, *Australopithecus africanus* — Carnivorous, *Homo habilis* — Carnivorous, *Homo erectus* — Omnivorous, *Homo sapiens sapiens* — Omnivorous.

5. Find out through internet and popular science articles whether animals other than man has self-consciousness.

✓ Yes, chimpanzee is the most near to the man than any other living animals. It has self-consciousness.

6. List 10 modern-day animals and using the internet resources link it to a corresponding ancient fossil. Name both.

✓ **Modern day**

Ancient Fossil

- | | |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Modern horse (<i>Equus</i>) | 1. <i>Eohippus</i> (= <i>Hydracotherium</i>) — Dawn horse — The first fossil found in the evolution of horse. |
| 2. Camel (<i>Camelus</i>) | 2. <i>Protylopus</i> . The first ancestor of modern camel. |
| 3. Modern elephant (<i>Elephas</i>) | 3. <i>Moeritherium</i> . The ancestor of modern elephant. |
| 4. Man (<i>Homo sapiens</i>) | 4. <i>Ramapithecus</i> oldest of man's ancestors. |
| 5. Vertebrates | 5. Jawless primitive fish like animals collectively known as ostracoderms (e.g, <i>Jamoytius</i>). |
| 6. Reptiles | 6. <i>Seymouria</i> — missing link between amphibian and reptile. |
| 7. Birds | 7. <i>Archaeopteryx</i> — Missing link between reptile and bird. |
| 8. Mammals | 8. <i>Cynognathus</i> — Missing link between reptile & mammal. |
| 9. Apes and Mammals | 9. <i>Dryopithecus</i> — Common ancestor of apes & mammals |
| 10. Frogs, Toads and Salamanders | 10. Some stem Amphibians called <i>Labyrinthodontia</i> (e.g., <i>Eryops</i>) gave rise to modern Amphibians such as Frog, Toads and Salamanders. |

7. Practise drawing various animals and plants.

✓ Practice to be done.

8. Describe one example of adaptive radiation.

✓ Developement of different functional structures from a common ancestral form is called adaptive radiation. Darwin's Finches are an example of adaptive radiation. They had common ancestors but now have different types of modified beaks according to their food habits.

9. Can we call human evolution as adaptive radiation ?

✓ No. Human evolution is not adaptive radiation.

10. Using various resources such as your school Library or the Internet and discussions with your teacher, trace the evolutionary stages of any one animal say horse.

✓ Refer to the text Evolution of Horse.

TEXT QUESTIONS**One Mark Questions (With Answers)**

1. What do you call that type of evolution in which changes in gene frequencies within a population occur over successive generations ?
✓ Microevolution.
2. Name the first probable compound molecules on earth.
✓ Water, ammonia.
3. Which were the organisms first began to release oxygen as a by-product of photosynthesis?
✓ Cyanobacteria.
4. Who used the term 'Hot dilute soup' ?
✓ Haldane.
5. Who used the phrase 'Survival of the fittest' first time ?
✓ Herbert Spencer.
6. Who is named father of palaeontology ?
✓ **Leonarda da Vinci** (Italian 1452-1519).
7. Which era is called age of reptiles ?
✓ Mesozoic era
8. Who obtained protenoid microspheres by heating a mixture of dry amino acids to 130 – 180°C and later cooling them in water ?
✓ Sydney Fox (1950)
9. Name the following –(i) A living fossil (ii) A missing link (iii) A connecting link.
✓ *Sphenodon*, *Archaeopteryx*, Lung fish.
10. What do you call that evolutionary phenomenon that produces changes in allele frequencies by random events ?
✓ Genetic drift.
11. In which epochs did the human evolution occur ?
✓ Pliocene.
12. What is the significance of the Lederberg experiment ?
✓ It demonstrates that preexisting gene mutation is the basis of adaptation.
13. Name the common ancestor of great apes and man.
✓ *Dryopithecus*
14. Write the probable differences in eating habits of *Homo habilis* and *Homo erectus*. (CBSE 2016)
✓ *Homo habilis* probably did not eat meat while *Homo erectus* ate meat.
15. According to de-Vries what is saltation ? (CBSE 2016)
✓ Saltation is single step large mutation that leads to the formation of new species (speciation).
16. State two postulates of Oparin and Haldane's theory with reference to the origin of life. (CBSE 2017)
✓ (i) The first form of life came from pre-existing non-living organic molecules.
(ii) The conditions on earth favouring chemical evolution were high temperature and reducing atmosphere.
17. What role does an individual organism play as per Darwin's theory of natural selection? (CBSE 2017)
✓ As an individual organism adds variations by random mating and nature selects the fittest organism, resulting in inheritance of useful variations and evolution of new species.

Two Mark Questions (With Answers)

1. (i) Select the homologous structures from the combinations give below :
 - (a) Forelimbs of whales and bats.
 - (b) Tuber of potato and sweet potato.
 - (c) Eyes of octopus and mammals.
 - (d) Thorns of *Bougainvillea* and tendrils of *Cucurbita*.

(CBSE 2015)

(ii) State the kind of evolution they represent.

✓ (i) *Homologous* structures are (a) Forelimbs of whales and bats and (d) thorns of *Bougainvillea* and tendrils of *Cucurbita*.(ii) They represent **divergent evolution**, i.e., the same structures developed along different directions due to the adaptations to different needs.

2. Mention the evolutionary significance of the following organisms.

(CBSE 2017)

(a) Shrews (b) Lobefins (c) *Homo habilis* (d) *Homo erectus*.**Three Mark Questions (Short Answer Type)**

- Who created coacervates artificially in the laboratory for the first time ? Enumerate their characteristics. What do they confirm about the origin of life ?
- Which is the most reliable evidence for evolution and why ?
- What is biogeography ? How do Darwin's finches provide the biogeographical evidence in favour of evolution ?
- How do the apes and humans differ with regard to vertebral column, pelvic girdle and feet ?
- Tabulate important differences between the atmosphere of the primitive earth and that of the present-day earth.
- What is genetic drift ? Give its significance in evolution.
- "Ontogeny repeats phylogeny." Explain it.
- Australian marsupials and placental mammals are suitable examples of adaptive radiation and convergent evolution. Explain giving reasons.
- According to Hardy-Weinberg's principle the allele frequency of a population remains constant. How do you interpret the change of frequency of alleles in a population ?

(CBSE 2009)



- Write your observations on the variations seen in the Darwin's finches shown above.
- How did Darwin explain the existence of different varieties of finches on Galapagos Islands?

(CBSE 2009)

- Explain the theory of biogenesis.
 - How did Miller demonstrate experimentally the chemical evolution that happened three billion years ago ?
- Mention any three characteristics of Neanderthal man that lived in Near East and Central Asia.
- Coelocanth* was caught in 1938 in South Africa. Why is it very significant in the evolutionary history of vertebrates ?
- Write the characteristics of *Ramapithecus*, *Dryopithecus* and Neanderthal man.
- $p^2 + 2pq + q^2 = 1$. Explain the algebraic equation on the basis of Hardy Weinberg's principle.

(CBSE 2014)

(CBSE 2010)

(CBSE 2017)

(CBSE 2017)

Five Mark Questions (Long Answer Type)

- Describe *Dryopithecus*, *Ramapithecus*, *Australopithecus*, *Homo erectus* and *Homo sapiens* giving brain size and function, skeletal structure, dietary preference, etc.
- What is adaptive radiation ? Explain it with reference to Australian marsupials. Can this fauna indicate it's parallel evolution with placental mammals ? How do you explain their geographic distribution ?
- State the Hardy-Weinberg's law.
 - Write the mathematical formula representing this law.
 - Under what conditions does the Hardy-Weinberg equilibrium remain undisturbed ?

4. How has the study of fossils helped in convincing scientists that organisms have come into existence through evolution? How can the age of fossil be determined?
5. What is meant by biogeography? Discuss the biogeographic evidence in support of organic evolution.
6. (a) Compare, giving reasons, the J-shaped and S-shaped models of population growth of a species.
(b) Explain 'fitness of a species', as mentioned by Darwin. (CBSE 2017)
7. (a) How do the observations made during moth collection in pre- and post-industrialised era in England support evolution by Natural Selection?
(b) Explain the phenomenon that is well represented by Darwin's finches other than natural selection. (CBSE 2017)

Value Based Questions with Answers

1. Penicillin drug was used for most bacterial infections. But it not so effective now-a-days. What are the possible reasons?
✓ Mutations took place in these bacteria to resist the attack by antibiotics like penicillin (Lederberg and Lederberg, 1952).
2. Mrs Santosh Puri gave birth to a child with small tail.
Read the above sentence and answer the following questions :
(i) What is your opinion about child?
(ii) What is atavism?
(iii) What will be your role as a student of biology?
✓ (i) Actually, the child is normal and carries the vestigial organ, i.e., remnant of last vertebra.
(ii) It is the reappearance of our ancestral characters.
(iii) As a biology student, I will educate people about vestigial organs and phenomenon of atavism so that they stop believing in myths.
3. Rakesh's father had severe pain in the abdomen. Rakesh took him to the hospital where he was diagnosed appendicitis. Doctors advised immediate surgical removal of vermiform appendix.
Read the above passage and answer the following questions :
(i) What is appendicitis?
(ii) What is vermiform appendix?
(iii) What value was displayed by Rakesh.
✓ (i) Appendicitis is an inflammation of vermiform appendix.
(ii) It is a vestigial organ in human beings and has no function in our body.
(iii) Rakesh was concerned about the health of his father.
4. In 1831, Darwin got an opportunity to travel on H.M.S. Beagle. The voyage lasted for five years (1831–1836). Darwin visited the Galapagos Islands ("called a living laboratory of evolution") in 1835. Birds of these islands influenced Darwin to think about evolutionary change. These birds were called finches.
Read the above passage and answer the following questions.
(i) Name the ship in which Charles Darwin sailed around the world.
(ii) Which islands are called a 'living laboratory of evolution'?
(iii) Name the birds which influenced Darwin to think about evolutionary change.
✓ (i) H.M.S. Beagle ; (ii) Galapagos Islands ; (iii) Finches

Multiple Choice Questions (With Answers)

- (1) According to Darwin, the organic evolution is due to
(a) competition within closely related species (b) reduced feeding efficiency in one species due to the presence of interfering species (c) intraspecific competition (d) interspecific competition. (NEET 2013)
- (2) Which one of the following is also called Sewall Wright effect?
(a) Isolation (b) Gene pool (c) Genetic drift (d) Gene flow. (Karnataka CET 2013)

- (3) The Scientist related with the theory of biogenesis and who has done experiment with swan-necked flask is (a) Haeckel (b) Louis Pasteur (c) van Helmont (d) Miller. (J & K CET 2013)
- (4) The mammals (animals) from colder climates generally have shorter hair and not fully developed ear, eyes and other phenotypic characters. This is known as (a) Dallas' law (b) Allen's rule (c) Cope's law (d) Bergmann's law. (J & K CET 2013)
- (5) The rise of 1st primates occurred in _____ epoch. (Maharashtra CET 2014)
(a) Palaeocene (b) Oligocene (c) Miocene (d) Eocene.
- (6) The hominid fossils discovered in Java in 1891 revealed a stage in the human evolution, which was called (a) *Homo erectus* (b) *Dryopithecus* (c) *Australopithecus* (d) *Homo habilis* (e) *Ramapithecus*. (Kerala PMT 2014)
- (7) Which one is an example of living fossil?
(a) Coral (b) *Ascidia* (c) *Octopus* (d) King crab. (WBJEE 2014)
- (8) Which compounds were used by Miller in his experiment for obtaining amino acids and other organic substances?
(a) Ammonia, methane, hydrogen and water vapour (b) Carbon dioxide, water vapour and methane (c) Ammonia, methane and carbon dioxide (d) Methane, ammonia, water vapour and hydrogen cyanide. (Karnataka CET 2014)
- (9) Which one of the following refers to Allen's rule.
(a) An organism can move from a stressful habitat to a more hospitable area and return when the stressful period is over (b) If the stressful conditions are localized or remain only for a short duration, an organism either migrates or suspends itself (c) Low atmospheric pressure in higher altitudes results in altitude sickness (d) Mammals from colder climates have shorter ears and limbs to minimize heat loss. (Karnataka CET 2014)
- (10) Just as a person moving from Delhi to Shimla to escape the heat for the duration of hot summer, thousands of migratory birds from Siberia and other extremely cold northern regions move to (a) Western Ghat (b) Meghalaya (c) Corbett National Park (d) Keoladeo Ghana National Park. (CBSE 2014)
- (11) Forelimbs of cat, lizard used in walking; forelimbs of whale used in swimming and forelimbs of bats used in flying are an example of (a) analogous organs (b) adaptive radiation (c) homologous organs (d) convergent evolution. (CBSE 2014)
- (12) The species continued to a particular region and not found elsewhere is termed as (a) keystone (b) alien (c) endemic (d) rare. (AIPMT 2015)
- (13) Industrial melanism is an example of (a) Neo Darwinism (b) natural selection (c) mutation (d) Neo Lamarckism. (AIPMT 2015)
- (14) The wings of a bird and the wings of an insect are (a) homologous structures and represent divergent evolution (b) analogous structures and represent convergent evolution (c) phylogenetic structures and represent divergent evolution (d) homologous structures and represent convergent evolution. (AIPMT 2015)
- (15) The first human-like hominid was called (a) *Homo habilis* (b) *Homo erectus* (c) *Homo sapiens* (d) *Dryopithecus* (e) *Ramapithecus*. (Kerala PMT 2015)
- (16) The idea of 'Natural Selection' as the fundamental process of evolutionary changes was reached (a) independently by Charles Darwin and Alfred Russel Wallace in 1859 (b) by Charles Darwin in 1866 (c) by Alfred Russel Wallace in 1901 (d) independently by Charles Darwin and Alfred Russel Wallace in 1859. (J & K CET 2015)
- (17) *Archaeopteryx* is a connecting link between (a) pisces and amphibians (b) amphibians and reptiles (c) reptiles and birds (d) birds and mammals. (WB JEE 2015)
- (18) Darwin's theory of evolution cannot explain (a) arrival of fittest (b) natural selection (c) prodigality of production (d) struggle for existence. (MH CET 2015)

- (19) The formation of two species from one ancestral species is known as
(a) convergent evolution (b) phyletic evolution (c) allopatry (d) divergent evolution. (KCET 2015)
- (20) Which of the following shows similarity with first man ?
(a) *Homo neanderthalensis* (b) *Australopithecus* (c) *Homo erectus* (d) *Homo habilis*. (EAMCET 2015)
- (21) One of the following period witnessed the maximum diversity of reptiles
(a) Cretaceous (b) Jurassic (c) Pleistocene (d) Triassic. (Chhattisgarh PMT 2015)
- (22) Foot prints, trails, tracks and tunnels of various organisms made in mud are rapidly filled in with sand and covered by sediments. This is an example of which of the following types of fossil ?
(a) Petrified fossil (b) Impressions (c) Imprints (d) Coprolites. (AMU 2015)
- (23) Which of the following structures is homologous to the wing of a bird ?
(a) Wing of a Moth (b) Hind limb of Rabbit (c) Flipper of Whale (d) Dorsal fin of a Shark. (NEET-I-2016)
- (24) Following are the two statements regarding the origin of life (i) the earliest organisms that appeared on the earth were non-green and presumably anaerobes (ii) the first autotrophic organisms were the chemoautotrophs that never released oxygen.
Of the above statements which one of the following options is correct ?
(a) (ii) is correct but (i) is false (b) Both (i) and (ii) are correct (c) Both (i) and (ii) are false (d) (i) is correct but (ii) is false. (NEET-I-2016)
- (25) Analogous structures are a result of (a) convergent evolution (b) shared ancestry (c) stabilizing selection (d) divergent evolution. (NEET-I-2016)
- (26) Genetic drift operates in (a) small isolated population (b) large isolated population (c) non-reproductive population (d) slow-reproductive population. (NEET-II-2016)
- (27) In Hardy-Weinberg equation, the frequency of heterozygous individual is represented by
(a) p^2 (b) $2pq$ (c) pq (d) q^2 (NEET-II-2016)
- (28) The chronological order of human evolution from early to the recent is
(a) *Australopithecus* → *Ramapithecus* → *Homo habilis* → *Homo erectus* (b) *Ramapithecus* → *Australopithecus* → *Homo habilis* → *Homo erectus* (c) *Ramapithecus* → *Homo habilis* → *Australopithecus* → *Homo erectus* (d) *Australopithecus* → *Homo habilis* → *Ramapithecus* → *Homo erectus*. (NEET-II-2016)
- (29) Which of the following is the correct sequence of events in the origin of life ?
I. Formation of protobionts
II. Synthesis of organic monomers
III. Synthesis of organic polymers
IV. Formation of DNA-based genetic systems
(a) I, II, III, IV (b) I, III, II, IV (c) II, III, I, IV (d) II, III, IV, I. (NEET-II-2016)
- (30) Artificial selection to obtain cows yielding higher milk output represents
(a) directional as it pushes the mean of the character in one direction (b) disruptive as it splits the population into two, one yielding higher output and the other lower output (c) stabilising followed by disruptive as it stabilises the population to produce higher yielding cows (d) stabilising selection as it stabilises this character in the population. (NEET 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given. One is assertion (A) and one is reason (R). Mark the correct answer as

- (A) If both A and R are true and R is correct explanation of A.
(B) If both A and R are true but R is not the correct explanation of A.
(C) If A is true but R is false.
(D) If both A and R are false

1. **Assertion :** The first living organisms were heterotrophs

Reason : They were surrounded by preformed organic molecules which they used as food.

- (A) (B) (C) (D)

2. **Assertion :** New life comes only from the preexisting life.
Reason : Spontaneous generation of life under the present environmental conditions on earth is not possible.
(A) (B) (C) (D)
3. **Assertion :** Life originated by chance coming together of necessary chemicals through a series of chemical reactions (abiogenesis)
Reason : Abiogenesis has not been experimentally proved.
(A) (B) (C) (D)

ANSWERS**Multiple Choice Questions**

- (1) —d (2) —c (3) —b (4) —b (5) —a (6) —a (7) —d (8) —a (9) —d (10) —d
(11) —c (12) —c (13) —b (14) —b (15) —a (16) —d (17) —c (18) —a (19) —d (20) —a
(21) —a (22) —b (23) —c (24) —b (25) —a (26) —a (27) —b (28) —b (29) —c (30) —a

Assertion and Reason type Questions

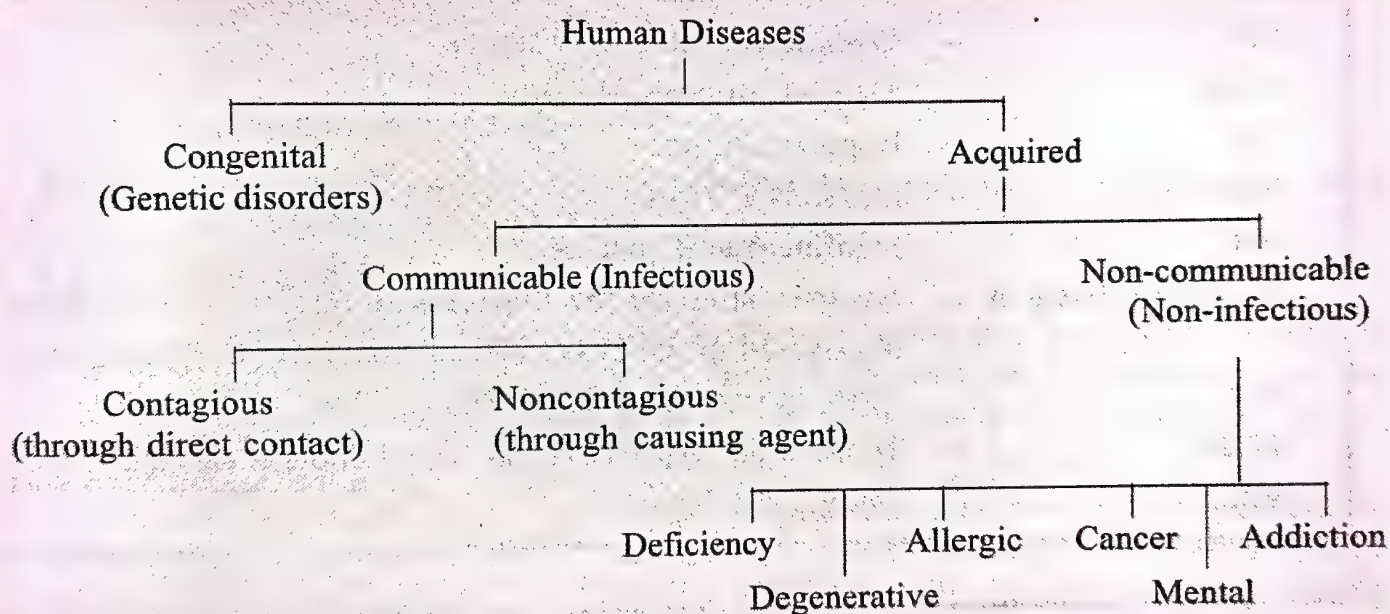
- (1) —A (2) —A (3) —C

Meaning of Health. Health may be defined as *state of complete physical, mental and social well being and not only absence of disease.*

COMMON DISEASES IN HUMANS

TYPES OF DISEASES

The diseases can be broadly grouped into two types— congenital diseases and acquired diseases.



Some Diseases and Their Confirmatory Tests

Test	Disease
1. Schick Test	Diphtheria
2. Wassermann Test	Syphilis
3. Widal Test	Typhoid/Paratyphoid
4. Wayson Stain Test	Bubonic Plague
5. Lepromin Skin Test	Leprosy
6. Dick Test	Scarlet Fever
7. Tourniquet Test	Dengue Fever
8. Ames Test/Elisa	Carcinogenic Diseases
9. Mantoux Test	Tuberculosis
10. R.A. Factor	Rheumatoid Arthritis

- | | | |
|-----|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| 11. | Well-Felix Test | Typhus Fever |
| 12. | ELISA (Enzyme—
Linked Immunosorbent Assay) | AIDS can be diagnosed by ELISA,
Western Blotting Test is employed
for confirmation of ELISA positive cases |
| | ELISA is also used to diagnose Hepatitis B and Hepatitis C | |
| 13. | PCR (Polymerase Chain Reaction) | Genital Herpes, AIDS, |
| 14. | VDRL (Venereal Disease Research
Laboratory) | Syphilis |
| 15. | Pap's Test | Cancer of Cervix |
| 16. | Rose-Waaler Test | Rheumatoid Factor |
| 17. | PSA (Prostatic Specific Antigen) Test | Cancer of Prostate |

Abbreviations of Some Vaccines

BCG	—	Bacillus Calmette – Guerin
OPV	—	Oral Polio Vaccine
DPT	—	Diphtheria, Pertussis Tetanus
MMR	—	Measles, Mumps, Rubella
HAV	—	Hepatitis A Virus
HBV	—	Hepatitis B Virus
HIB	—	H influenzae B vaccine
Australia Antigen	—	Another name for the 'hepatitis B antigen which was first discovered in the blood of an Australian aborigine (tribe)
TAB	—	Typhoid paratyphoid A and B vaccine
TABC	—	Typhoid paratyphoid A and B and cholera vaccine
ATS	—	Antitetanus Serum

Discovery of Some Vaccines

Vaccine	Discovered By
1. Toxoid Vaccine for Diphtheria	Eismil von Behring (got Nobel Prize in 1901)
2. Vaccine Against Small Pox	Edward Jenner
3. Rabies, Anthrax and Cholera Vaccines	Louis Pasteur
4. Cellular Immunity to tuberculosis	Robert Koch
5. Yellow fever vaccine	M. Theiler (got Nobel Prize in 1951 for this)
6. B. C. G. (Bacillus Calmette Guerin) Vaccine	Calmette and Guerin
7. Vaccine Against Hepatitis B	Blumberg (got Nobel Prize in 1976 for this)
8. Injectable Polio Vaccine (IPV)— Salk Vaccine	Jonas Salk
9. Oral Polio Vaccine (OPV) — Sabin Vaccine	Albert Bruce Sabin

Differences between Vaccine and Antiserum

Vaccine	Antiserum (pl. Antisera)
<ol style="list-style-type: none"> 1. Vaccine is a preparation of attenuated (weakened) or dead pathogens of a disease. 2. It provides active immunity, that lasts for longer period. 	<ol style="list-style-type: none"> 1. Antiserum is serum that contains antibodies, usually from an animal that has been deliberately exposed to a particular antigen. 2. It provides passive immunity, that lasts for shorter period.

I. COMMUNICABLE DISEASES

Classification. Communicable diseases are classified into nine types according to the nature of the pathogen (causing agent).

1. Viral diseases, 2. Rickettsial diseases, 3. Mycoplasmal diseases, 4. Chlamydial diseases, 5. Bacterial diseases, 6. Spirochaetal diseases, 7. Protozoan diseases, 8. Helminthic diseases and 9. Fungal diseases.

1. VIRAL DISEASES

1. Poliomyelitis or Polio (Infantile Paralysis)

Pathogen. *Enterovirus (Poliovirus)*.

Modes of Transmission. Polio virus usually enters the body via alimentary canal (faecal oral route) where it multiplies and reaches the nervous system through the blood stream.

Incubation Period. 7 to 14 days

Signs and Symptoms. It produces inflammation of the nervous system. Stiffness of the neck is an important sign. Paralysis starts following the weakness of particular skeletal muscles. The attack of paralysis begins with high fever, headache, chilliness, pain all over the body.

Prevention and Treatment. There must be provided an adequate arrangement for proper disposal of urine and faeces of the patient, because they contain polio virus. Overcrowding of children in schools, playgrounds and cinema halls should be avoided. Polio is preventive. Polio vaccine is safe and effective. The first polio vaccine was prepared by **Jonas Salk** (1953). The killed virus is called "**Salk Vaccine**" and injected to develop immunity. Jonas Salk is called "father of polio vaccine".

Sabin *et al* prepared an oral vaccine known as OPV (Oral Polio Vaccine).

2. Rabies (Hydrophobia)

Pathogen. *Rabies virus*.

Symptoms and Modes of Transmission. The virus is introduced in the body by the bite of rabid (mad) dogs usually. It can be injected by the bite of jackals, wolves, cats etc.,

Incubation period. 10 days to one year.

Signs and Symptoms. *Fear of water* is the most important characteristic symptom of this disease. Other symptoms are saliva from the mouth, severe headache, high fever, alternating periods of excitement and depression, inability to swallow even fluids due to choked throat. The virus destroys the brain and spinal cord. **Rabies is 100% fatal.**

Prevention and Treatment. There should be compulsory immunisation of dogs and cat population. All ownerless and stray dogs should be destroyed. Wound of the bitten person should be immediately washed with soap and water. After this give antirabies vaccine to the patient. The pet should be watched for 10 days after it has bitten some one to make sure that it does not have rabies virus.

3. Viral Hepatitis

Symptoms. It is commonly called jaundice. Viral hepatitis is the most important form of hepatitis. In early stage the liver is enlarged and congested. In later stage the liver becomes smaller, yellowish or greenish. The symptoms in early phase include— fever, anorexia, nausea, vomiting, epigastric discomfort, pains in muscles and joints. The urine is dark and stool is pale. Splenic enlargement is sometimes present.

Types. There are 6 types of viral hepatitis. These are Hepatitis A, Hepatitis B, Hepatitis C, Hepatitis D, Hepatitis E and Hepatitis G. These (except Hepatitis G) are given below in table form. There is no Hepatitis F.

Characteristic Features of Different Types of Hepatitis

Feature	*Hepatitis A	Hepatitis B	Hepatitis C	Hepatitis D	Hepatitis E
1. Name of virus	HAV	HBV	HCV	HDV	HEV
2. Nucleic Acid present in virus	RNA	DNA	RNA	RNA	RNA
3. Transmission	Faecal oral Route	*Parenteral; (Blood, Needle, Body secretion, Placenta, Sexual contact)	Parenteral; (Blood)	Parenteral; (Blood, coinfection with hepatitis B)	Faecal oral Route
4. Symptoms	Fever, headache, gastro intestinal disturbance, dark urine, jaundice	Similar, to HAV but no headache. Severe liver damage, yellowish eyes, light coloured stools,	Similar to HBV more likely to become chronic	Severe liver damage, high mortality rate	Similar to HAV but pregnant women may have high mortality
5. Incubation Period	2–6 weeks	6 weeks–6 months	2–22 weeks	6–26 weeks	2–6 weeks
6. Vaccine	Hepatitis A virus vaccine	Genetically modified vaccine	No	HBV vaccine is protective	No
7. Chronic Hepatitis	None	Yes	Yes	Yes	No

Some new techniques have provided evidence of blood transmitted virus known as hepatitis G (HGV). The HGV is more prevalent than HCV. HGV is closely related to HCV. Hepatitis C is clinically similar to Hepatitis B. Antigen of Hepatitis B virus is called **Australia antigen**.

*Also called infectious hepatitis.

*Parenteral. Taken into the body in a manner other than through digestive tract.

* World Hepatitis Day — May, 19.

4. Chikungunya

Pathogen. It is caused by *Chikungunya virus*. This virus was first isolated from human patients and *Aedes aegypti* mosquitoes from Tanzania in 1952. The name 'Chikungunya' is derived from the native word for the disease in which patient lies "doubled up" due to severe joint pains. Epidemics of chikungunya have occurred in many African countries.

Mode of Transmission. By the bite of *Aedes aegypti* mosquito. No vaccine is available.

Signs and Symptoms. Its symptoms include sudden onset of fever, crippling joint pains, lymphadenopathy and conjunctivitis. Some show haemorrhagic manifestations. The fever is typically biphasic. Chikungunya is found in India.

Incubation Period. Usually 3–6 days

Prevention and Treatment. Preventive measures include elimination of mosquitoes and their eggs. Paracetamol is given to reduce fever, analgesic (drug that relieves pain) drugs such as aspirin for the joint pain. Bed rest and adequate fluid intake are also recommended.

5. Dengue Fever (*Break-bone fever*)

Pathogen. Dengue fever is caused by mosquito borne *flavi-ribo virus*.

Mode of Transmission. The virus of dengue fever is transmitted by the bite of *Aedes aegypti* (tiger mosquito). *Aedes* mosquito breeds in clean water and bites only during day time.

Incubation Period. 3 to 8 days

Types of Dengue Fever. Two types of dengue fever are common: classical dengue fever and dengue haemorrhagic.

(a) **Symptoms of Classical Dengue Fever.** (i) Sudden onset of high fever. (ii) Severe frontal headache. (iii) Pain behind the eyes which worsens with eye movement. (iv) Muscles and joint pains. (v) Loss of appetite. (vi) Rashes on the body. (v) Nausea and vomiting.

(b) **Symptoms of Dengue Haemorrhagic Fever.** Symptoms similar to classical dengue fever except the following :— (i) Bleeding from the nose, mouth, gums and skin bruising. (ii) Severe and continuous stomach pains. (iii) Frequent vomiting with or without blood. (iv) Pale cold or clammy skin. (v) Excessive thirst (dry mouth). (vi) Rapid weak pulse. (vii) Difficulty in breathing. (viii) Restlessness and constant crying.

No vaccine for Dengue fever is available. Dengue test is available.

Prevention and Treatment. Mosquitoes and their eggs should be eliminated. Wear clothes that cover the body.

No specific therapy is available. Symptomatic care including bed rest, adequate fluid intake and analgesic medicine is recommended. Do not take aspirin and dispirin. Use Paracetamol (tablet, syrup) for fever.

6. Common Cold/Rhinitis

Pathogen. It is one of the most infectious human disease caused by *Rhino* viruses. The viruses attack the nose and respiratory passage but not the lungs.

Modes of Transmission. The viruses are transmitted through inhalation of droplets from infected person or through contaminated objects (droplet infection).

Incubation Period. 3 to 7 days.

Signs and Symptoms. The common cold is characterised by nasal congestion, excessive nasal secretion, very sore throat, cough, headache, etc.

Treatment. Antihistamins and decongestants are used as drugs to treat common cold. No vaccine is available.

Other Viral Diseases of Humans

Disease	Pathogen	Symptoms	Mode of Spread and Incubation Period	Vaccine, Treatment (Drugs)
1. Influenza (Flu)	<i>Orthomyxovirus</i> (Influenza virus)	Sore throat, headache, fever, sneezing, pain all over the body, nasal	Droplet Infection IP 1-4 days	Influenza vaccine available
2. *Small pox (Variola)	<i>Variola virus</i> It has been iradicated, last case was found in Somalia, Oct 1977.	High fever, small vesicles containing clear fluid on the skin, scars left	Droplet infection, direct contact IP 12-days	Vaccine was discovered by Edward Jenner in 1798.
3. Chicken pox (Varicella)	<i>Varicella zoster virus</i>	Mild fever, rashes, aches, no scar left	Droplet infection, direct contact IP 14-21 days	Varicella Vaccine
4. Mumps (Infectious Parotiditis)	<i>Paramyxo virus</i>	Painful swelling of the parotid (salivary) glands on one or both sides	Droplet infection IP 16-18 days	MMR Vaccine
5. Measles (Rubeola Disease)	<i>Rubeola virus</i>	Reddish rash appears on neck which spreads over body.	Droplet infection IP 10 days	MMR Vaccine
6. Rubella *(German Measles)	<i>Rubella virus</i>	Bright red rash begins on the face, spreads rapidly on whole body. Rash fainter than measles, arthritis	Droplet infection (virus enters through the nasopharynx) IP 12-23 days	MMR Vaccine Pregnant woman should not be given vaccine
7. Yellow Fever	<i>Flavi virus</i>	Sudden high fever, severe pain in joints, chilliness, skin becomes yellow in colour, vomiting, urine contains high levels of albumin.	By bite of <i>Aedes aegypti</i> , mosquitoes IP 3-4 days	Vaccine available.
8. *SARS- Severe Acute Respiratory Syndrome	SARS- <i>Coronavirus</i>	High fever, chills, headache, dizziness, sore throat, running nose, nausea, vomiting, diarrhoea, trouble in breathing	Infection from the patient's secretions from the nose, mouth and throat IP 2 to 7 days	SARS is mostly diagnosed by PCR (polymerase chain-reaction) test.

*Donald Hopkins (1941-) was instrumental in eradicating small pox. It is the first and only disease to be eradicated by medical science.

• Saiban Bibi (24-5-1975) was the last small pox case seen in India

*It is so called because it was first decribed by German physician in the 18th Century and in appearance it is similar to measles.*SARS was first reported in China.

9. Swine Influenza (Swine Flu)	Triple-reassorted flu virus A (H1N1)	In humans symptoms are fever, cough, sore throat, bodyache, chills and fatigue.	Infection is from swine (old use of pig)	Indigenous A (H1N1) vaccine.
10. Genital Herpes	<i>Herpes simplex virus</i>	Ulcers over external genitalia and perianal region. Fever, headache, pain, itching, vaginal and urethral discharge. Diagnosed by PCR.	Sexual contact 1P 2–7 days	
11. Genital Warts	<i>Human Papilloma virus (HPV)</i>	Warts (benign hard, out-growths with horny surface develop over the skin of external genitalia and perianal area.	Sexual intercourse	

Note : AIDS is also viral disease which is to be discussed ahead.

2. RICKETTSIAL DISEASES

These are caused by rickettsiae (the obligate intracellular parasites). The Rickettsiae were formerly considered closely related to viruses. Examples : Rocky Mountain Spotted Fever (RMSF), Rickettsial pox, trench fever, *Q fever and epidemic typhus fever.

3. MYCOPLASMAL DISEASES

Mycoplasma are the smallest free living microorganism. They lack a rigid cell wall and hence they are one of the **pleomorphics** (having many shapes). They can produce filaments which resemble fungi mycelia hence their name (*mykes*– fungus and *plasma* – formed).

A typical Pneumonia Pathogen— *Mycoplasma pneumoniae* was discovered by Eaton in 1941.

Transmission. It is by droplets of nasopharyngeal secretions.

Symptoms. The disease is characterised by scarcity of respiratory signs on physical examination, low fever, cough, headache.

Incubation Period. 1 to 3 weeks.

Treatment. Tetracyclines are the drugs of choice. Penicillins are of no use.

4. CHLAMYDIAL DISEASES

Chlamydia are also microorganisms that are intracellular parasites. Since the chlamydiae are obligate intracellular parasites, they were previously thought to be viruses. They are in between bacteria and viruses. *Chlamydiae* differ from viruses in having cell wall, both DNA and RNA and in multiplying by binary fission. **Example** : Trachoma

5. BACTERIAL DISEASES

1. Typhoid (Enteric fever)

Pathogen. *Salmonella typhi*.

*For query, so named because pathogen was unknown.

Modes of Transmission. Faecal oral route.

Typhoid Mary. It is a classic case in medicine. Mary Mallon was a cook by profession and was a typhoid carrier. She continued to spread typhoid for several years through the food she prepared.

Incubation Period. It is 1–3 weeks.

Signs and Symptoms. There is high fever but pulse rate is low. The patient feels abdominal pain and passes frequent stools. Confirmed by **Widal Test**. Typhoid vaccine is available.

Treatment. The patient is treated with antibiotics such as **Terramycin** and **Chloromycetin**.

2. Pneumonia

Pathogen. *Streptococcus pneumoniae* and *Haemophilus influenzae*. Pneumonia is a serious disease of the lungs.

Modes of Transmission. The disease spreads by sputum of the patient.

Incubation period. 1–3 days.

Signs and Symptoms. Lymph and mucus collect in the alveoli and bronchioles of the lungs so that the lungs do not get sufficient air. Therefore, proper exchange of gases does not take place in the alveoli. No vaccine is available

Treatment. Use of **Penicillin**, **Streptomycin** and **Ampicillin**.

3. Cholera

Pathogen. *Vibrio cholerae*.

Modes of Transmission. Faecal Oral Route. **Robert Koch** (1843–1910) discovered cholera. **John Snow** (1913) was the first to demonstrate that cholera is transmitted by contaminated water.

Incubation period. It varies from a few hours to 2–3 days.

Signs and Symptoms. The patient starts passing stools frequently, which are white like rice water, and gets repeated vomiting. The disease can be diagnosed by the microscopic examination of the stool or the vomit when the typical comma-shaped cholera vibrios can be seen.

Treatment. Rapid replacement of fluid and electrolytes is needed by **oral rehydration-therapy**. You can make your own **oral rehydration solution (ORS)** at home by adding one teaspoon of sugar and a pinch of salt to one quarter of water. Drugs tetracycline and chloramphenicol are used.

4. Tuberculosis (TB) or Koch's Disease

Pathogen. *Mycobacterium tuberculosis*.

Modes of Transmission. The bacteria damage the tissues and release a toxin named **tuberculin** which produces the disease. It affects the lungs, lymph nodes, bones and joints.

Modes of infection includes infection by inhalation of droplets expelled by tubercular patients, infection of food and drink contaminated with bacteria of tuberculosis, milk from a tubercular cow, etc.

Incubation period. 3 – 6 weeks (variable).

Signs and Symptoms. Symptoms of pulmonary (lungs) tuberculosis are fever, cough, blood containing sputum, pain in the chest and loss of weight, excessive fatigue, failure of appetite, slight rise of temperature in the evening, hoarseness of throat, night sweating and rapid pulse. Diagnosis of TB is done by **Mantoux Test**.

Prevention and Treatment. BCG vaccine gives protection against tuberculosis. When coughing, he/she should keep the handkerchief before his/her mouth. Tuberculosis is curable.

Isoniazid, Streptomycin and Rifampicin drugs are used to treat Tuberculosis.

Other Bacterial Diseases of Humans

Disease	Pathogen	Symptoms	Mode of Spread and Incubation Period	Vaccine
1. Diphtheria Diagnosis of the disease is done by Schick Test	<i>Corynebacterium diphtheria</i>	Sore throat, hoarseness, difficulty in breathing.	Droplet infection IP 2 to 5 days.	DPT vaccine
2. Whooping cough (Pertussis)	<i>Bordetella pertussis</i>	Whooping sound, face becomes red during coughing, convulsions.	Droplet infection IP 10 – 16 days	DPT vaccine
3. Tetanus (Lock Jaw)	<i>Clostridium tetani</i>	Spasms of muscles of the jaw and face, severe pain often fatal.	Wound infection IP 3 – 25 days.	DPT vaccine
4. Leprosy (Hansen's Disease)	<i>Mycobacterium leprae</i>	Light coloured patches on skin. Diagnosis is done by Lepromin Skin Test .	Through prolonged contact.	No vaccine is available
5. Bacillary Dysentery (Shigellosis)	<i>Shigella dysenteriae</i>	Abdominal pain, blood & mucus in the stools.	Faecal oral route IP variable.	No vaccine available,
6. Anthrax	<i>Bacillus anthracus</i>	Anthrax comes from animals to human beings and is of three types — (i) Cutaneous Anthrax , (ii) Pulmonary Anthrax & (iii) Intestinal Anthrax	Spores of <i>B. anthracus</i> are the source of infection.	Anthrax vaccine available
7. Bubonic Plague (Black Death)	<i>Yersinia pestis</i>	High fever, bubo in groin or the armpit. Diagnosis is done by Wayson Stain Test .	Its bacteria are transmitted from rat flea to man.	Antiplague vaccine available
8. Gonorrhea	<i>Neisseria gonorrhoeae</i> (named after Albert Neisser who isolated it in 1879)	In male the disease starts as an acute inflammation of urethra, painful urination and discharge of pus from the penis. In female the symptoms are abdominal discomfort, vaginal discharge, abnormal uterine bleeding, pelvic inflammation, sterility.	It is STD and is spread through sexual contact IP 2 to 5 days	No vaccine is available

9. Botulism (Food Poisoning)	<i>Clostridium botulinum</i>	Swollen tongue, double vision, vomiting, diarrhoea.	Faecal oral route IP is usually 18 to 36 hours. Sexual contact	No vaccine available
10. Chancroid	<i>Haemophilus ducreyi</i>	Ulcer appears at the site of infection generally over external genitalia. It is painful and bleeds easily.		
11. Scarlet Fever	<i>Streptococcus pyrogenes</i>	The symptoms are high fever, rash on the body and tonsillitis and Pharyngitis. Tongue is also affected. The rash subsides after 6 to 9 days. The Dick test is done to know the presence of an immunity to scarlet fever.	Infection is through contact with another individual carrying the organisms.	Vaccine not available

6. SPIROCHAETAL DISEASES

Spirochaetes are flexible, twisted round the long axis microorganisms. The characteristic feature is the presence of varying numbers of fine fibrils between the cell wall and cytoplasmic membrane. Example : **Syphilis** (According to some authors syphilis is a bacterial disease).

Syphilis

Pathogen. *Treponema pallidum*

Mode of Transmission. It is a sexually transmitted disease (STD) which is also known as venereal disease (VD). However, *T. pallidum* can be transmitted from an infected mother to the developing foetus across the placenta which is called **congenital syphilis**.

Incubation Period. 2 to 3 weeks

Symptoms. The symptoms of syphilis occur in four stages : (i) **Primary syphilis.** A red painless ulcer called a **chancre** appears at the site of the spirochaete infection. In males this is usually the penis but in females it is often the vagina or the cervix. (ii) **Secondary syphilis.** It includes fever, general enlargement of lymph nodes, a pink skin rash all over the body and joint pain. (iii) **Latent Syphilis.** In this stage there is no sign and symptom of the disease. (iv) **Tertiary syphilis.** It is characterized by tumour like masses called **gummas**. Tertiary syphilis may cause serious damage to the heart and blood vessels (**Cardiovascular syphilis**) or bones and skin.

Diagnosis. VDRL test is done to detect the syphilis.

Treatment. Penicillin is still the drug of choice for syphilis (all stages).

Differences between Gonorrhoea and Syphilis

Gonorrhoea	Syphilis
<ol style="list-style-type: none"> 1. Causing agent- <i>Neisseria gonorrhoea</i>. 2. Urethral discharge is pus. 3. Microscopic examination of urethral pus smear is by gram stain. 4. CFT Test (Complement Fixation Test) is done. 	<ol style="list-style-type: none"> 1. Causing agent - <i>Treponema pallidum</i>. 2. Chancre (lesions on genital part). 3. Spirochaete can be demonstrated in the material collected from chancre by dark ground microscope. 4. VDRL Test is done.

7. PROTOZOAN DISEASES

1. Malaria

Pathogen. Malarial parasite (= *Plasmodium*). *Plasmodium* has two hosts :

(a) **Female Anopheles Mosquito.** As the sexual phase of the malarial parasite occurs in the mosquito it is considered the **definitive** (= **primary**) **host** of malarial parasite.

(b) **Human beings.** As the asexual phase of the malarial parasite occurs in man, it is considered the **intermediate** (= **secondary**) **host**.

As the female *Anopheles* mosquitoes feed on blood, only they can serve as **vector hosts** (= **carrier**) of malarial parasites. The parasite do not harm the mosquito.

Historical Aspects. **Lancisi** (1717) first suspected a relationship between swamp, malaria and mosquito. **Laveran** (1880) discovered that malaria is caused by protozoan parasite. In fact he discovered *Plasmodium*. He got Nobel Prize in 1907. His topic of discovery was "Role of Protozoans in Causing Disease". **Golgi** (1885) confirmed Laveran's discovery by observing stages of *Plasmodium malariae* in human RBCs. In 1897 **Sir Ronald Ross**, a doctor who was born at Almora in India and he was in Indian Army, established that malarial parasite is transmitted by the bite of a female *Anopheles* mosquito. In 1902, he got Nobel Prize for this discovery. He worked in India.

Life Cycle of *Plasmodium* (Fig. 8.1)

Life cycle of *Plasmodium* requires two hosts for completion, such a two host life cycle is called **digenetic**.

I. Life Cycle of *Plasmodium* in Man

1. Infective stage of *Plasmodium* is sporozoite. When the mosquito bites another human, sporozoites are injected with bite.
2. Parasites (sporozoites) reach the liver through blood.
3. The parasite reproduces asexually in liver cells, bursting the cell and releasing into the blood.
4. Parasites enter the red blood cells and reproduce asexually there bursting the red blood cells and causing cycles of fever and other symptoms. Released parasites infect new red blood cells.
5. Sexual stages (gametocytes) develop in red blood cells.

II. Life Cycle of *Plasmodium* in Female *Anopheles* mosquito

1. Female mosquito takes up gametocytes with blood meal.
2. Fertilisation and development take place in the mosquito's stomach.
3. The zygote elongates and becomes motile called **ookinete**.
4. The ookinete moves and bores through the wall of the stomach of female *Anopheles* mosquito. The ookinete changes to **oocyst** on the surface of the stomach.
5. Inside the oocyst, sporozoites are formed which are released in the body cavity of the mosquito.
6. Mature infective stages (sporozoites) move to different organs of the body cavity but many of them penetrate salivary glands of the mosquito.
7. When the female *Anopheles* mosquito bites a healthy person, the sporozoites are injected in his/her blood alongwith saliva.

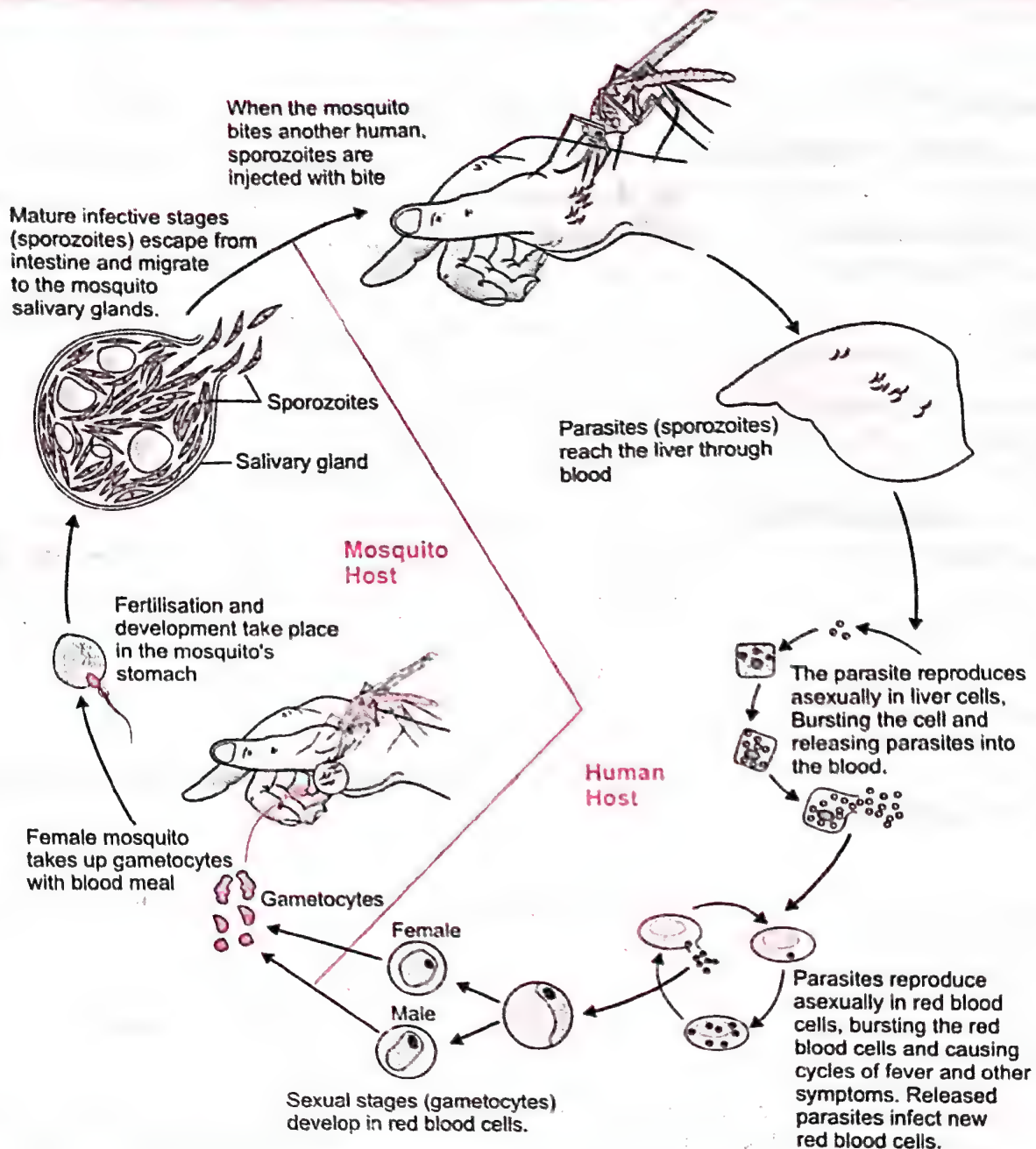


Fig. 8.1. Life cycle of Malarial Parasite.

Human Species of *Plasmodium* and Types of Malaria. In human beings, malaria is caused by four species.

1. ***Plasmodium vivax*.** It is most common in India. It is less common in Africa. Its incubation period is about 14 days. It causes **Benign Tertian Malaria**. Recurrence of fever is after every 48 hours (every third day). Recurrent attacks of fever is called paroxysms.

2. ***Plasmodium falciparum*.** It is common in certain parts of India. It is the greatest killer of human beings over most parts of Africa and else where in tropics. Its incubation period is about 12 days. Recurrence of fever is after every 48 hours (every third day). It causes **Malignant (=Aestivo-autumnal or Pernicious or Cerebral or Tropical) Tertian Malaria**.

3. ***Plasmodium malariae*.** It is common in tropical Africa, Burma, Sri Lanka and parts of India. It is less common in India. *This was the species of malarial parasite discovered by*

Laveran. This is the only species which can also infect other primates. Its incubation period is 28 days. Recurrence of fever is after 72 hours (every 4th day). It causes **Quartan Malaria**.

4. *Plasmodium ovale*. This is the *rarest of the four species* which infect man. It is *mostly found in tropical Africa*. It is usually not seen in India. Its incubation period is about 14 days. It causes **Mild Tertian Malaria**.

Pigment granules (dots) in the cytoplasm of infected RBCs in four Species of <i>Plasmodium</i>			
<i>P. vivax</i>	<i>P. falciparum</i>	<i>P. malariae</i>	<i>P. ovale</i>
Schuffner's dots	Maurer's dots	Ziemann's dots	Jame's dots

Symptoms of Malaria. The patient displays symptoms of malaria fever after a period of 14 days from infectious bite. Early restlessness, less appetite and slight sleeplessness are followed by muscular pains, headache and a feeling of chilliness. In response to chills the body temperature starts rising and may reach 106°F at the height of fever. The patient sweats a lot and the temperature steadily goes down to normal, till the next attack takes place after 48 hours.

Control of Malaria. Malaria is widely spread disease in India . There is separate anti-malaria department of the government which controls malaria through National Malaria Eradication Programme (NMEP).

(a) **Treatment of the patient.** Quinine, the oldest drug for malaria, and other drugs are also used for this purpose. Quinine is extracted from the bark of the **cinchona tree** which is mostly growing in West Indies, India, Sri Lanka, Java and Peru. Other anti-malarial drugs are **paludrine** and **Primaquin**, **Chloroquinine**, **Camoquin** and **Comoprime**. Now malaria is also being treated with sulpha drugs such as **sulphadoxin**, **dapsone**, etc.

(b) **Prevention of Infection.** Ducks, larvivorous fish like *Gambusia*, some adult insects like dragon flies, insectivorous plants such as *Utricularia*, are the natural enemies of mosquito larvae and pupae as they feed upon them. These may be introduced in the water containing the larvae and pupae.

2. Amoebiasis (= Amoebic Dysentery; Enteritis)

Pathogen. *Entamoeba histolytica*

Host. It is **monogenetic** (single host life cycle, i.e., humans).

Discovery. **Lamble** (1859) discovered *Entamoeba histolytica*. **Losch** (1875) discovered its pathogenic nature.

Habitat. The pathogen lives in the large intestine of humans. It is more commonly found in males than females. Presence of **chromatoid bodies** is the characteristic of the cysts of *Entamoeba histolytica*.

Modes of Transmission. (i) **Faecal oral route.** (ii) **Sexual transmission.** (iii) **Vectors** such as flies, cockroaches, etc.

Incubation Period 2 to 4 weeks or more.

Mode of Infection. The cyst passes unaltered through the stomach. The cyst wall is resistant to the action of the gastric juice but is digested by the action of trypsin in the

intestine. Thus active parasites are liberated from the cyst into the intestine where it starts normal life. *E. histolytica* eats red blood corpuscles. **Tetranucleate cyst** is infective stage.

E. histolytica is **dimorphic**, i.e., occurs in two forms larger harmful **magna** form and smaller harmless **minuta** form.

Diagnosis. Presence of **Charcot-Leyden crystals** made up of protein, normally found in the cytoplasm of eosinophils. Presence of chromatoid bodies is the characteristic of *E. histolytica*.

Incubation Period. It varies in humans but is generally 4 or 5 days.

Symptoms. In amoebic dysentery (amoebiasis) the patient passes blood along with the faeces and feels pain in the abdomen.

Prevention and Treatment. Symptomatic treatment includes the use of **Metronidazole** and **Tinidazole**.

3. Giardiasis (= Diarrhoea)

It is caused by a zooflagellate protozoan named *Giardia intestinalis*. *Giardia* was discovered by **Leeuwenhoek** in his own stools in 1681. It is the first human parasitic protozoan known. It lives in the upper parts (**duodenum** and **jejunum**) of human small intestine. It absorbs nourishment from the food passing through intestine, grow and multiply through binary fission. The large number of parasites interfere with digestion and absorption of food. This causes epigastric pain, abdominal discomfort, diarrhoea, headache and sometimes fever. The diseases caused by *Giardia* is popularly known as **giardiasis** or **diarrhoea** (watery and frequent stools).

4. Trypanosomiasis

It includes African Trypanosomiasis and American Trypanosomiasis.

(i) **African Trypanosomiasis (African Sleeping Sickness).** Its pathogens are transmitted by bite of tse tse fly (*Glossina palpalis* and *G. morsitans*). The pathogens are found in blood but later enter the cerebrospinal fluid and migrate to the brain. The patient becomes lethargic and unconscious. Because of it the disease is called sleeping sickness. African Trypanosomiasis is of two types (a) **Gambian Trypanosomiasis** (West African Sleeping Sickness) caused by *Trypanosoma gambiense* and (b) **Rhodesian Trypanosomiasis** (East African Sleeping Sickness) caused by *Trypanosoma Rhodesiense*.

(ii) **American Trypanosomiasis** (American Sleeping Sickness or **Chagas Disease**). Chagas disease occurs rarely in the United States and Mexico but is more common in South America particularly Brazil. Its pathogen is *Trypanosoma cruzi* which is transmitted by "kissing bugs" (triatomids). The bugs pass the infectious parasites in the faeces. The infectious parasites enter the host through damaged skin or mucous membrane. The parasite is found in blood. The patient becomes lethargic. In Chagas disease other symptoms are fever, cardiac dilation, digestive tract damage, enlargement of spleen, etc.

5. Leishmaniasis or Kala-azar (Dum-Dum Fever).

It is caused by *Leishmania donovani*. The parasite is transmitted by *Phlebotomus argentipes* (sandfly). Its symptoms are continuous fever, anaemia, enlargement of liver, spleen, etc.

6. Trichomoniasis (Vaginitis, Leucorrhoea)

It is caused by *Trichomonas vaginalis*. It lives in the vagina of women. The symptoms of this disease are burning sensation, itching and frothy discharge. In males the parasite produces irritation in urethra. Its transmission is through sexual act.

7. Balantidiasis (= Balantidium Dysentery)

It is caused by *Balantidium coli*. This parasite lives in the human large intestine (colon). It feeds on human red blood corpuscles, tissue fragments, undigested food and bacteria. It also undergoes cyst formation. Cysts are passed out in the host's faeces. Infection occurs by ingesting cysts with food and water. *Balantidium coli* invades mucous membrane of the colon by secreting an enzyme **hyaluronidase**. The parasite causes ulcers in the human colon and diarrhoea but may also lead to severe dysentery. Ciliary dysentery can be prevented by protecting food articles from dust and flies that carry cysts of *Balantidium coli*.

8. HELMINTHIC DISEASES

These diseases are caused by flat worms and round worms.

Platyhelminths (Flatworms) and Nematodes (Round worms) constitute the Helminths.

(A) Diseases Caused by Flat Worms

Disease	Pathogen	Site of Infection	Mode of Infection	Secondary Host	Effect
1. Fasciolopsiasis	<i>Fasciolopsis buski</i> – The Intestinal Fluke	Small Intestine of man	Metacercariae on water plants	<i>Segmentina</i> or <i>Planorbis</i> (snails)	Intestinal inflammation, ulcer, diarrhoea
2. Schistosomiasis	<i>Schistosoma haematobium</i> (Blood fluke)	Portal and mesenteric veins of man	Cercariae in water penetrate the skin when come in contact	<i>Bulinus</i> or <i>Melania</i> (snails)	Urogenital schistosomiasis
3. Taeniasis	<i>Taenia solium</i> (Pork tapeworm)	Small Intestine of man	By eating ill cooked meaty pork	Pig	Taeniasis (Intestinal disorders)
4. Taeniasis	<i>Taenia saginata</i> (Beef tapeworm)	Small Intestine of man	By eating ill cooked beef	Cattle	Intestinal disorders & anaemia
5. Cysticercosis It is more dangerous than taeniasis	<i>Cysticercus</i> (larva of tapeworm)	Ingestion of eggs or oncospheres reach the stomach from intestine by antiperistalsis of intestine where oncospheres (larvae) develop into cysticerci (larvae). From stomach cysticerci reach the eyes and brain	Ingestion of eggs of tapeworm or they reach lower part of digestive tract and develop into cysticerci & reach the eyes and brain	Man	In the eye cysticercus can cause blindness & in the brain it can cause epilepsy
6. Hydatid Disease	<i>Echinococcus granulosus</i> (Dog tapeworm or Hydatid worm)	In the intestine of dogs, cats, foxes and men	By playing with pet dogs.	Man, sheep, goat, pig and cat	The parasite liberates toxins which have harmful effect on the body & brain of the host

(B) Diseases Caused by Nematodes (Round Worms)

1. Ascariasis

Pathogen. It is caused by *Ascaris lumbricoides*.

Host and Infection. *Ascaris* is an endoparasite of the small intestine of human beings. It is more common in the children, because the latter are generally in the habit of eating soil and clay, which may be infected by the eggs of *Ascaris*. Second stage juvenile— also called **embryonated egg**, is infective stage. There is no secondary host in the life cycle of this parasite.

Route of the Parasite / Juveniles and Moulds Fertilized eggs → Out with host faeces → First stage juvenile in egg— also called **Rhabditiform larva (First mould)** → 2nd stage juvenile— also called **embryonated egg** (infective juvenile in egg) → Embryo-nated egg swallowed by man with food → 2nd stage juvenile becomes free in human intestine → 2nd stage juvenile bores through intestinal wall into blood capillaries → Heart → 3rd stage juvenile in lung alveoli (**2nd mould**) → 4th stage juvenile in lung alveoli (**3rd mould**) → Bronchioles (**4th stage juvenile**) → Bronchi → Trachea → Pharynx → Intestine (**4th mould**) → Young worms.

Symptoms. Since a large number of adult *Ascaris* worms normally infest a single host, they obstruct the intestinal passage and thereby cause abdominal discomforts, like colic pains. The patient may also suffer from indigestion, *diarroheu* and *vomiting*.

Treatment and Prevention. The disease can best be treated by administering antihelminthic drugs such as **oil of chenopodium**, **Alcopar**, **Bendex**, **Dewormis**, **Zental**, etc. **Mebendazole** is the drug of choice. The parents should see to it that their children do not take to the habit of eating soil.

2. Filariasis (Elephantiasis)

Pathogen. Filariasis is caused by a number of worms. But in India only two types of worms are responsible and are called *Wuchereria bancrofti* and *W. malayi*.

Transmission. The infestation is transmitted by female *Culex* mosquitoes from one individual to the others. The worms live in the lymphatic system.

Symptoms. This disease is characterised by the swelling of the legs and scrotum. The disease is, therefore, commonly known as **elephantiasis** due to its resemblance to a leg of an elephant.

Treatment. **Albendazole** with **Diethylcarbamazine** (DEC-hetrazan) is the commonly used drug.

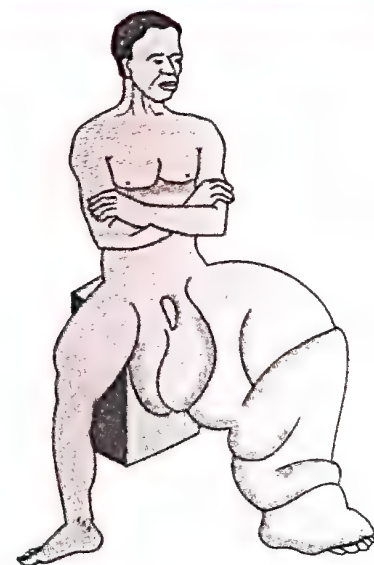


Fig. 8.2. A person suffering from elephantiasis.

Other Diseases Caused by Round Worms

Disease	Pathogen	Site of Infection	Mode of Infection	Effect
1. Ancylostomiasis	<i>Ancylostoma duodenale</i> (Hookworm)	Small Intestine	Larvae bore through the skin of feet	Itching and Inflammation of skin, anaemia, mental & physical deficiency
2. Enterobiasis (Oxyuriasis)	<i>Enterobius vermicularis</i> (Pin worm)	Caecum & Colon appendix	By swallowing eggs with food	Anal itching, appendicitis, nervous trouble
3. Trichinellosis	<i>Trichinella spiralis</i> (<i>Trichina</i> worm)	Encysted larvae in striated muscles, adults in intestine	By eating half cooked infected pork	Muscular pain, pneumonia
4. Dracunculiasis	<i>Dracunculus medinensis</i> (Guinea worm)	Subcutaneous tissue	Taking infected <i>Cyclops</i> with water	Ulcers, diarrhoea, asthma, giddiness
5. Trichuriasis	<i>Trichuris trichiura</i> (Whipworm)	Caecum and appendix	By taking eggs with food	Abdominal pain, anaemia, bloody stools
6. Loiasis (Eye worm disease)	<i>Loa Loa</i> (Eye worm)	Subcutaneous tissue of eyes	By bite of infected deerfly (<i>Chrysops</i>)	Conjunctivitis

9. FUNGAL DISEASES

These are caused by fungi. Fungi had been discovered as causative agents of human diseases earlier than bacteria. Study of fungal diseases in humans is called **Medical Mycology**. The fungal diseases of man are either **mycoses** (caused by infection of fungi) or **toxicoes** (caused by toxic fungal metabolites). The term *myco* refers to a fungus and *osis* or *iosis* means condition.

Ringworm or Tinea

A long time ago people believed that worms lived in the scaly ring, hence the name the ringworm or tinea.

Pathogen. Fungi belonging to genera *Trichophyton*, *Epidermophyton* and *Microsporum* are responsible for ringworm or tinea in man.

Mode of Infection. The infection is generally acquired from soil or by using towels, clothes or even the comb of infected persons.

Effects of three Genera. Effects of three genera *Trichophyton*, *Epidermophyton* and *Microsporum* are given below.

(i) ***Trichophyton*.** Trichophytons infect skin, hair and nails. *T. rubrum* is the most common species infecting man.

(ii) ***Epidermophyton*.** It attacks the skin and nails but not the hair, e.g., *E. floccsum*.

(iii) ***Microsporum*.** It infects the hair and skin but usually not the nails, e.g., *M. canis*.

Treatment. Griseofulvin (orally) and Miconazole (topically).

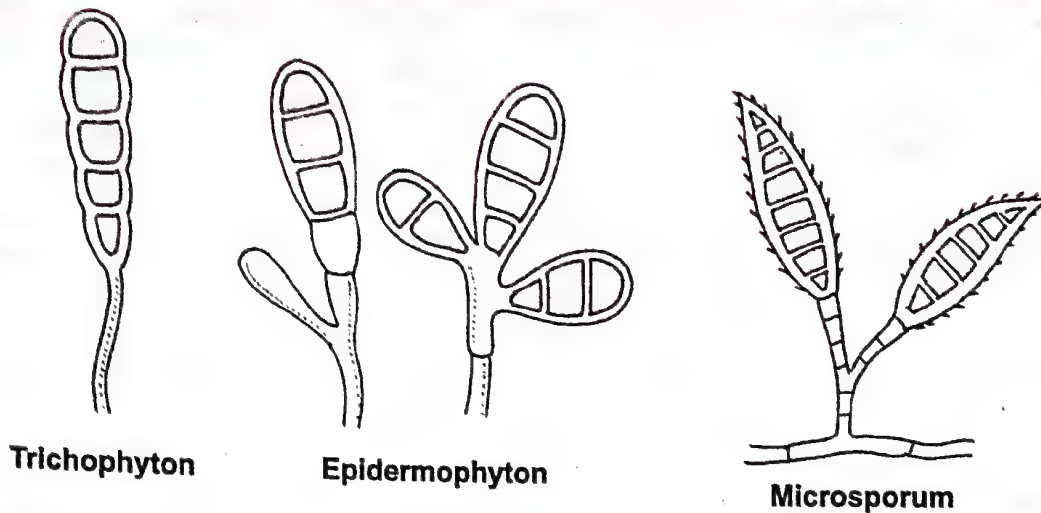


Fig. 8.3. Figure showing three genera of ringworm.

Some Types of Tinea or Ringworm (According to the Affected Parts)

(i) *Tinea pedis* (**athletes' foot**) is ringworm of the foot. Drug **Tolnaftate** is used to cure the athlete's foot. (ii) *Tinea capitis*—ringworm of the scalp. (iii) *Tinea cruris*—involvement of the groin and perineum. (iv) *Tinea barbae*—involvement of the bearded areas of the face and neck.



Fig. 8.4. Ringworm of foot.



Fig. 8.5. Ringworm of Scalp.



Fig. 8.6. Ringworm of beard areas of the face and neck.

II. NON-COMMUNICABLE DISEASES

The non-communicable diseases remained confined to the persons who suffer from them. These are not transmitted from infected persons to other persons. Some important non-communicable diseases are described here.

(A) Diabetes mellitus (Hyperglycemia)

The most common endocrine disorder of the pancreas is the diabetes mellitus, now recognised to exist in two forms—Insulin-dependent and non-insulin-dependent. The **insulin-dependent diabetes mellitus (IDDM)** is caused by a failure of the Beta-cells to produce adequate amounts of insulin due to an **autoimmune response**, while the **non-insulin-**

***Candidiasis.** It is an opportunistic infection. Certain organisms which are usually nonpathogenic and do not invade the blood or tissues, become pathogenic when the host's body defenses are impaired, a.e called as **opportunistic organisms**.

dependent diabetes mellitus (NIDDM) appears to involve failure of insulin to facilitate the movement of glucose into cells. In both disorders the blood glucose concentration is elevated above the normal range. Some of the glucose is excreted in the urine, and water follows the glucose, causing excessive urination and dehydration of body tissues. This causes frequent drinking of water because of extreme thirst (**polydipsia**). The cells are unable to utilize glucose and other carbohydrates for energy production. They utilize their proteins for it. The person becomes very weak. Degradation of fats increases, producing ketone bodies (**keto-sis**). The latter are acidic and poisonous. Blood cholesterol level rises. Healing power is impaired. Administration of insulin lowers the blood-glucose level. It gives relief to the patient.

Differences between Type I and Type II Diabetes

<i>IDDM (Type I)– Juvenile Diabetes</i>	<i>NIDDM (Type II)</i>
<ol style="list-style-type: none"> 1. Onset less than 20 years. 2. Normal weight. 3. Ketoacidosis common. 4. Severe insulin deficiency. 5. Beta-cell depletion. 	<ol style="list-style-type: none"> 1. Onset more than 30 years. 2. Obese. 3. Ketoacidosis rare. 4. Relative insulin deficiency. 5. Mild beta-cell depletion.

(B) Cardiovascular Diseases

The diseases that affect the blood vessels and the heart are called cardiovascular diseases. These are as follows :

1. **Hypertensive Heart Diseases.** These include : (a) **Arteriosclerosis.** Hardening and loss of elasticity of the arteries is commonly referred to as arteriosclerosis. It causes hypertension or high blood pressure. (b) **Atherosclerosis** (Gk. *Athero*– gruel, *sclerosis*–hardening). In this disease a lumpy thickness develops on the inner walls of the arteries that prevents the dilation of vessels (arteries). The vessels become smaller in diameter and cannot fully expand. It is considered that a variety of dietary sodium is sometimes restricted. (c) **Hypertension** (High blood pressure). It is defined as a resting arterial pressure exceeding 120/80 over a prolonged period of time. Disorders that can result from untreated hypertension include heart failure, kidney damage and cerebro-vascular accident (rupture of a cerebral artery sometimes called a stroke). Hypertension is classified as essential or primary hypertension (when the exact cause is not known) and as secondary hypertension (when the cause is known). About 90% of all cases of hypertension are essential hypertension. The remaining 10% are due to excess secretion of *epinephrine* by the adrenal medulla, *aldosterone* by the adrenal cortex and *renin* by kidney. Treatment generally involves the use of drugs that inhibit the action of the sympathetic nervous system. Dietary sodium is sometimes restricted.

2. **Coronary Heart Diseases.** The coronary arteries, which supply blood to the muscles of the heart, are among the most important blood vessels of the body. They supply oxygen and nutrients to the heart and coronary veins carry carbon dioxide and other metabolic wastes from the wall of the heart. Coronary heart diseases include (a) **Angina Pectoris.** Sclerosis of the coronary arteries can cause “pain in the chest”. This anginal pain usually starts in the centre of the chest and spreads down the left arm. The chest pain may be associated with restlessness, fear or anxiety, a pale skin, profuse sweating and vomiting. The pain lasts for only a few movements. (b) **Coronary Thrombosis or Myocardial Infarction**

12. Mendel used statistical methods and law of probability for analysing his results.

13. Mendel was lucky in selecting those traits, the factors (now called genes) of which did not interact. They were either present on different chromosomes or showed complete recombination. He did not combine pod shape and plant height in any of his dihybrid crosses the genes of which are close together on chromosome 4 and do not show frequent recombination.

14. He did not attempt to explain all the variations found in his results but left them as such, e.g., linkage of flower and seed colour.

THE CHANGING CONCEPT OF INHERITANCE

Mendel proposed that "something" was being passed down from the parents to offspring through the gametes over successive generation. This "something" was called by him a **factor** or **determiner**. According to him there is a pair of factors for each character, one inherited from each parent. **Johannsen** (1909) gave the term '**gene**' to the Mendelian factor. **Alleles** are slightly different forms of the same genes.

Genes are present on the chromosomes. A gene is considered to control the inheritance of one character (**unit of function**). But it was soon realized that a gene does not produce a character itself, although it may exercise the major control on its development. During 1940, it became evident that a gene controlled a single biochemical reaction by directing the production of a single enzyme (**one gene – one enzyme hypothesis**). But soon after, it was shown that one gene produces a single polypeptide and not one enzyme (**one gene one polypeptide hypothesis**). It is further established that gene is chemically a linear segment of DNA, now called **cistron**. Thus one cistron controls the production of one polypeptide in protein synthesis. Cistron is, therefore, considered unit of function and is accepted as a synonym for gene. **Recon** is subunit of cistron that undergoes recombination. **Muton** is also subunit of cistron that is capable of mutation. The terms cistron, recon and muton were given by **S. Benzer** in 1955.

Points To Remember

- Mendel himself did not propose any genetical principle or law. He simply gave conclusive theoretical and statistical explanations for his hybridization experiments in his research paper.

- It was **Correns** (1901) one of the three rediscoverers of Mendel's work who thought that Mendel's discovery could be the two Laws of heredity/inheritance which were named after Mendel's name. These laws of heredity/inheritance are ***Law of Segregation** (it is also called **Mendel's First Law** because this was actually the first law to be rediscovered) and the **Law of Independent Assortment** (it is also called Mendel's **Second Law**). Later on Mendel's postulate of dominance was raised to the status of ***Law of Dominance** by Correns (1901) but this law was not given any serial number.

- Mendel confirmed his own findings in pea with those in rajma (*Phaseolus vulgaris* L).
- The term allele/alleles is usually used instead of factor/factors while describing the Mendel's Laws of Inheritance.

- Mutation may change a gene into two or more alternative forms called alleles.
- Mendel did not know of genes, alleles and even chromosomes.
- DNA is usually genetic material but in some viruses such as

(ii) Influenza virus and (iii) Human Immunodeficiency virus, the genetic material is RNA.

*In NCERT Biology Text Book for class XII it is incorrectly mentioned as 'the First Law or Law of Dominance and the second Law or Law of segregation.

(E) Cancer. It is to be discussed ahead in this Chapter.

The following diseases under Genetic Disorders, have been discussed in Chapter 5 on Principles of Inheritance and Variations :

Down's Syndrome, Edward's Syndrome, Patau's Syndrome, Cri-du-chat Syndrome, Turner's Syndrome, Klinefelter's Syndrome, Superfemales, Supermales, Alkaptonuria, Phenylketonuria, Albinism, Tay-Sach's Disease, Gaucher's Disease, Sickle Cell Anaemia, Thalassaemias, Alzheimer's Disease, Haemophilia, Red-green colour blindness, Night blindness and Muscular dystrophy.

Parkinson's Disease (PD). Cause. It is caused by the destruction of the neurons that produce the neurotransmitter dopamine. Thus dopamine is reduced in the brain. **Symptoms** include tremors and shakes in the limbs, a slowing of voluntary movements and feeling of depression. **Treatment** is by dopamine. The drug Exelon, prescribed to restore memory in Alzheimer's patients, may also offer some help for people who develop dementia from Parkinson's disease. Great boxer Mohammad Ali was suffering from Parkinson's disease.

Robert Koch (1843 – 1910)— The first proof that bacteria actually cause diseases came from Robert Koch in 1876. He formulated **Koch's postulates** which are as follows.

(1) The organism (pathogen) must be regularly found in the body of the animal that is suffering from a disease. (2) The organism must be isolated that grow in pure culture on artificial media. (3) The same disease must be produced when the cultured organisms are injected into other healthy animals. (4) The same organism must be recovered from the injected animals.

Exceptions to Koch's Postulates. These postulates originally were applied for animal diseases but are equally applicable for human diseases. However, *Koch's postulates are not applicable to viral diseases and bacteria of leprosy* because virus and *Mycobacterium leprae* (causing leprosy) cannot be cultured on artificial media. Virus can only be cultured in a living cell.

- *Mycobacterium leprae* can be cultured in foot pad of Armadillo.
- Robert Koch discovered *Mycobacterium tuberculosis* (bacteria of TB) in 1882.
- Robert Koch also discovered *Vibrio cholerae* (bacteria of cholera) in 1883.

IMMUNITY

Definition. Immunity is the ability of the body to protect against all types of foreign bodies like bacteria, virus, toxic substances, etc. which enter the body. Immunity is also called **disease resistance**. The lack of immunity is known as **susceptibility**.

The science dealing with the various phenomena of immunity, induced sensitivity and allergy is called **immunology**.

Types of Immunity

There are two major types of immunity : innate or natural or nonspecific and acquired or adaptive.

(A) Innate or Natural or Nonspecific Immunity (*L. innatus* = inborn)

Innate immunity is inherited by the organism from the parents and protects it from birth throughout life. For example humans have innate immunity against **distemper**, a fatal disease of dogs.

As its name nonspecific suggests that it lacks specific responses to specific invaders.

Innate immunity or nonspecific immunity is well done by providing different barriers to the entry of the foreign agents into our body. *Innate immunity consists of four types of barriers—physical, physiological, cellular and cytokine barriers.*

1. **Physical Barriers.** They are mechanical barriers to many microbial pathogens. These are of two types. Skin and mucous membrane.

(a) **Skin.** The skin is physical barrier of body. Its outer tough layer, the **stratum corneum** prevents the entry of bacteria and viruses.

(b) **Mucous Membranes.** Mucus secreted by mucous membrane traps the microorganisms and immobilises them. Microorganisms and dust particles can enter the respiratory tract with air during breathing which are trapped in the mucus. The **cilia** sweep the mucus loaded with microorganisms and dust particles into the **pharynx** (throat). From the pharynx it is thrown out or swallowed for elimination with the faeces.

2. **Physiological Barriers.** The skin and mucous membranes secrete certain chemicals which dispose off the pathogens from the body. Body temperature, pH of the body fluids and various body secretions prevent growth of many disease causing microorganisms. Some of the important examples of physiological barriers are as follows:

(a) **Acid of the stomach** kills most ingested microorganisms. (b) **Bile** does not allow growth of microorganisms. (c) **Cerumen** (ear wax) traps dust particles, kills bacteria and repels insects. (d) **Lysozyme** is present in tissue fluids and in almost all secretions except in cerebrospinal fluid, sweat and urine. Lysozyme is in good quantity in tears from eyes. Lysozyme attacks bacteria and dissolves their cell walls. Lysoenzyme is also found in saliva. (e) **Nasal Hair.** They filter out microbes and dust in nose. (f) **Urine.** It washes microbes from urethra. (g) **Vaginal Secretions.** It is slightly acidic which discourages bacterial growth and flush microbes out of vagina. (h) **Sebum** (sweat). It forms a protective acid film over the skin surface that inhibits growth of many microbes.

3. **Cellular Barriers.** These are certain white blood corpuscles (leucocytes), macrophages, natural killer cells, complement system, inflammation, fever, antimicrobial substances, etc.

(i) **Certain Leucocytes.** Neutrophils and monocytes are major phagocytic leucocytes.

(a) **Polymorpho-nuclear Leucocytes (PMNL- neutrophils).** As they have multilobed nucleus they are normally called **polymorphonuclear leucocytes** (PMNL-neutrophils). Neutrophils are short lived and are highly motile phagocytic killers. Neutrophils are formed from stem cells in the bone marrow. Neutrophils are the most numerous of all leucocytes. They die after a few days and must therefore, be constantly replaced. Neutrophils constitute about 40% to 75% of the blood leucocytes in humans.

(b) **Monocytes.** They are the **largest** of all types of leucocytes and somewhat amoeboid in shape. They have clear cytoplasm (without cytoplasmic granules). The nucleus is bean-shaped. Monocytes constitute about 2–10% of the blood leucocytes. They are motile and *phagocytic* in nature and engulf bacteria and cellular debris. Their life span is about 10 to 20 hours. *Generally they change into macrophages after entering tissue spaces.*

(ii) **Macrophages.** Monocytes circulate in the bloodstream for about 8 hours, during which time they enlarge and then migrate into the tissues and differentiate into specific tissue macrophages. Macrophages are long lived and are highly motile phagocytic.

Macrophages contain more cell organelles especially lysosomes. Macrophages are of two types. (a) Some take up residence in particular tissues becoming **fixed macroph-**

ages and (b) whereas other remain motile and are called **wandering macrophages**. Wandering macrophages move by amoeboid movement throughout the tissues. Fixed macrophages serve different functions in different tissues and are named to reflect their tissue location. Some examples are given below :

- **Pulmonary alveolar macrophages** in the lung
- **Histiocytes** in connective tissues
- **Kupffer cells** in the liver
- **Glomerular Mesangial cells** in the kidney
- **Microglial cells** in the brain
- **Osteoclasts** in bone

(iii) **Natural Killer Cells (NK Cells)**. Besides the phagocytes, there are **natural killer cells** in the body which are a type of lymphocytes and are present in the spleen, lymph nodes and red bone marrow. NK cells do not have antigen receptors like T cells and B cells. NK cells cause cellular destruction in at least two ways :

(a) NK cells produce **perforins** which are chemicals that when inserted into the plasma membrane of a microbe make so weak that **cytolysis** (breakdown of cells particularly their outer membrane) occurs and creates pores in the plasma membrane of the target cells. These pores allow entry of water into the target cells, which then swell and burst. Cellular remains are eaten by phagocytes.

(b) Another function of NK cells is **apoptosis** which means natural cell death. It occurs naturally as part of the normal development, maintenance and renewal of cells, tissues and organs.

Thus functions of NK cells are to destroy target cells by cytolysis and apoptosis. NK cells constitute 5%–10% of the peripheral blood lymphocytes in humans.

(iv) **Complement** (Fig. 8.7). Complement is a group of over 30 proteins, many of which are enzyme precursors and are produced by the liver. These proteins are present in the serum of the blood (the fluid portion of the blood excluding cells and clotting factors) and on plasma membranes. They are found circulating in the blood plasma and within tissues throughout the body. They were named **complement** by **Ehrlich** because they complement the actions of other components of the immune system (*e.g.*, action of antibody on antigen) in the fight against infection. **Jules Bordet** is the discoverer of complement.

Complement proteins create pores in the plasma membrane of the microbes. Water enters the microbes. The latter burst and die. The proteins of complement system destroy microbes by (i) cytolysis (ii) inflammation and (iii) phagocytosis. These proteins also prevent excessive damage of the host tissues.

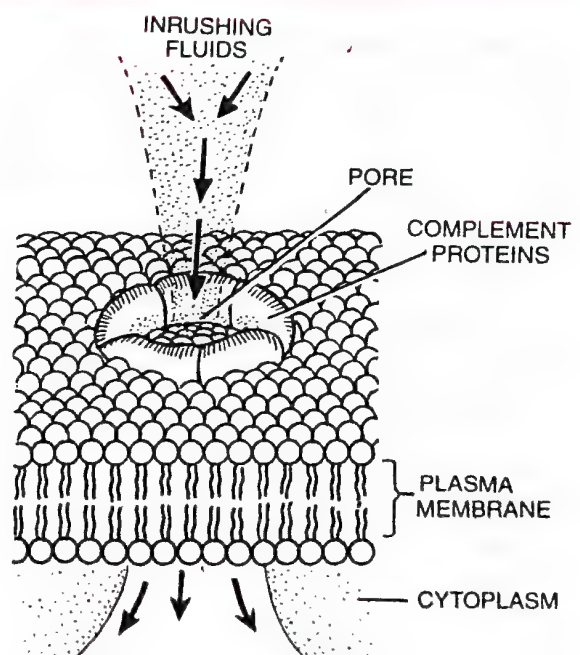


Fig. 8.7. Complement proteins creating a hole in the plasma membrane.

(v) **Inflammation.** Inflammation is a defensive response of the body to tissue damage. The conditions that may produce inflammation are pathogens, abrasions (scraping off) chemical irritations, distortion or disturbances of cells, and extreme temperatures. The signs and symptoms of inflammation are **redness, pain, heat and swelling**. Inflammation can also cause the **loss of function** in the injured area, depending on the site and extent of the injury. Inflammation is an attempt to dispose of microbes, toxins, or foreign material at the site of injury to prevent their spread to other tissues, and to prepare the site for tissue repair. Thus, it helps restore tissue homeostasis.

Broken mast cells release **histamine**. Histamine causes dilation of capillaries and small blood vessels. As a result more blood flows to that area making it red and warm and fluid (plasma) takes out into the tissue spaces causing its swelling. This reaction of the body is called **inflammatory response**.

(vi) **Fever.** Fever may be brought about by toxins produced by pathogens and a protein called **endogenous pyrogen** (fever producing substance), released by macrophages. When enough pyrogens reach the brain, the body's thermostat is reset to a higher temperature, allowing the temperature of the entire body to rise. Mild fever strengthens the defence mechanism by activating the phagocytes and by inhibiting the growth of microbes. A very high temperature may prove dangerous. It must be quickly brought down by giving antipyretics.

4. **Cytokine Barriers.** Cytokines (Chemical messengers of immune cells) are low molecular weight proteins that stimulate or inhibit the differentiation, proliferation or function of immune cells. They are involved in the cell to cell communication. Kinds of cytokines include **interleukines** produced by leucocytes, **lymphokines** produced by lymphocytes, **tumour necrosis factor** and **interferons** (IFNs). Interferons protect against viral infection of cells.

(B) Acquired Immunity (= Adaptive or Specific Immunity)

The immunity that an individual acquires after the birth is called **acquired or adaptive or specific immunity**. It is specific and mediated by antibodies or lymphocytes or both which make the antigen harmless. It not only relieves the victim of the infectious disease but also prevents its further attack in future. The memory cells formed by B cells and T cells are the basis of acquired immunity. Thus acquired immunity consists of specialized B and T lymphocytes and Antibodies.

Characteristics of Acquired Immunity

(i) **Specificity.** It is the ability to differentiate between various foreign molecules (foreign antigens).

(ii) **Diversity.** It can recognise a vast variety of foreign molecules (foreign antigens).

(iii) **Discrimination between Self and Non-self.** It can recognise and respond to foreign molecules (non-self) and can avoid response to those molecules that are present within the body (self) of the animal.

(iv) **Memory.** When the immune system encounters a specific foreign agent, (e.g., a microbe) for the first time, it generates immune response and eliminates the invader. This is called first encounter. The immune system retains the memory of the first encounter. As a result, a second encounter occurs more quickly and abundantly than the first encounter.

The cells of the immune system are derived from the **pluripotent stem cells** in the bone

marrow. Pluripotent means a cell that can differentiate into many different types of tissue cells. The pluripotent stem cells can form either myeloid stem cells or lymphoid stem cells. **Myeloid stem cells** give rise to monocytes, macrophages and granulocytes (neutrophils, eosinophils, and basophils). RBCs and blood platelets (**lymphoid stem cells**) form B lymphocytes (B cells), T lymphocytes (T-cells) and natural killer (NK) cells.

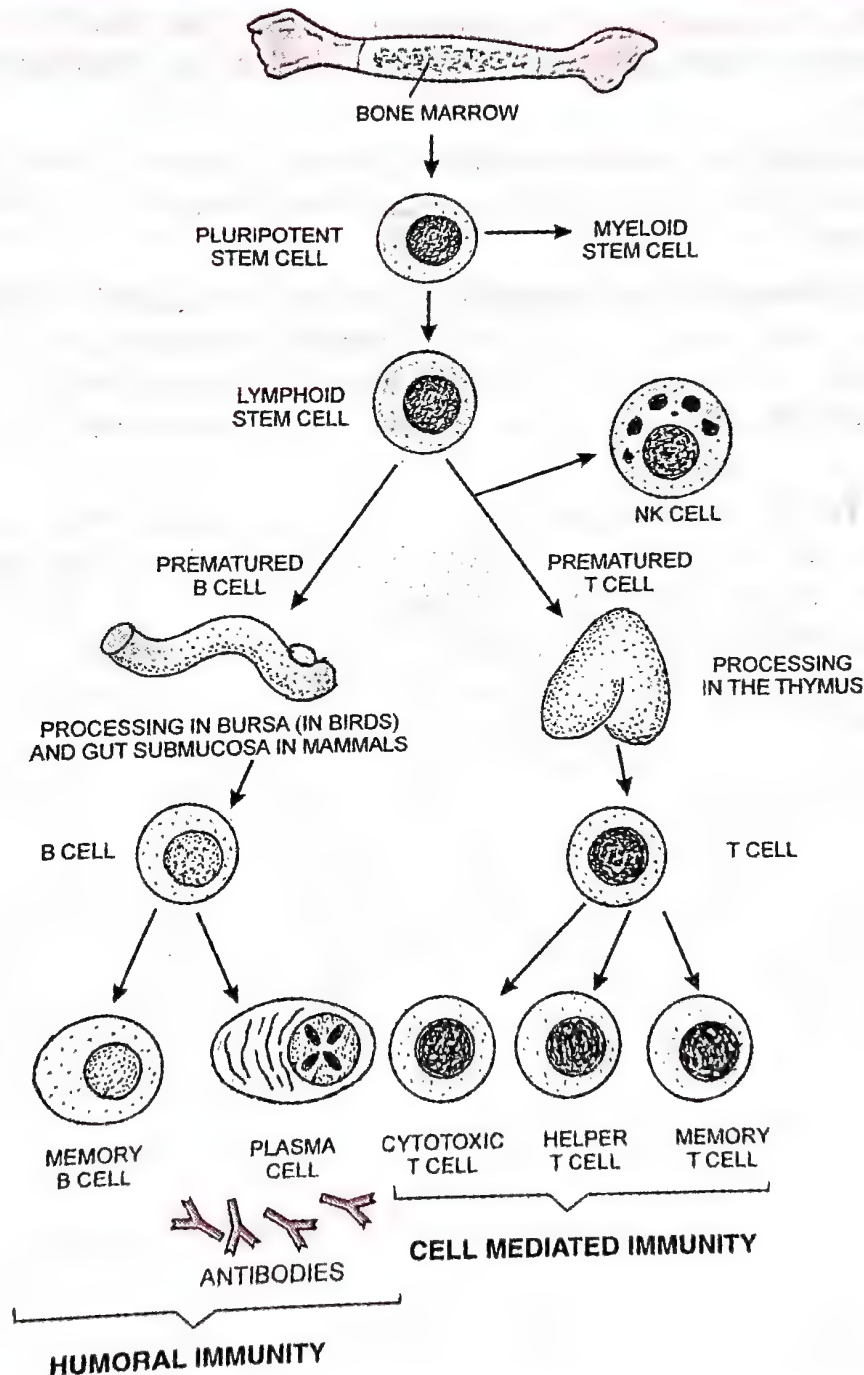


Fig. 8.8. Development of B and T lymphocytes. Both arise from bone marrow precursors. Natural killer (NK) cells are a third population of lymphocytes that are distinct from T cells and B cells.

Components of Acquired Immunity

Acquired immunity has two components : **humoral immunity** or **Antibody mediated immune system (AMIS)** and **cellular immunity** or **cell mediated immune system (CMIS)**.

I. Antibody Mediated Immune System (AMIS) or Humoral Immunity

It consists of antibodies (specialised proteins produced in the body in response to antigen) that circulate in the body fluids like blood plasma and lymph. The word 'humor' pertains to fluid. B lymphocytes (B cells) produce antibodies that regulate humoral immunity. The T-lymphocytes themselves do not secrete anti-bodies but help B lymphocytes produce them.

Certain cells of the bone marrow produce B lymphocytes and mature there. Since B lymphocytes produce antibodies, therefore, this immunity is called antibody mediated or humoral immunity.

Humoral immunity or antibody-mediated immune system (AMIS) provides defence against most extracellular bacterial pathogens and viruses that infect through the respiratory and intestinal tract.

Formation of Plasma B cells and Memory B cells. When antibodies on B cell's surface bind antigens (any substances that cause antibodies formation) the B cell is activated and divides, producing a clone (descendants of a single cell) of daughter B cells. These clones give rise to **plasma B cells** and **memory B cells**. This phenomenon is called **clonal selection**.

(a) **Plasma B Cells (Effector B cells).** Some of the activated B cells enlarge, divide and differentiate into a clone of plasma cells. Although plasma cells live for only a few days, *they secrete enormous amounts of antibodies during this period.*

(b) **Memory B Cells.** Some activated B cells do not differentiate into plasma cells but rather remain as **memory cells (Primed cells)**. They have a longer life span. The memory cells remain dormant until activated once again by a new quantity of the same antigen.

Role of AMIS. The AMIS protects the body from (i) viruses (ii) some bacteria and (iii) toxins that enter the body fluids like blood and lymph.

II. Cell-Mediated Immune System (CMIS) or T-Cell Immunity

A healthy person has about a trillion lymphocytes. Lymphocytes are of two types: T lymphocytes or T cells and B lymphocytes or B cells. As we know both types of lymphocytes and other cells of the immune system are produced in the **bone marrow**. The process of production of cells of immune system in the bone marrow is called **haematopoiesis**.

Because **T lymphocytes (T cells)** mature in the thymus, this immunity is also called **T-cell immunity**.

The T-cells play two important functions—**effector** and **regulatory**.

The effector function includes **cytolysis** (destruction of cells by immune processes) of cells infected with microbes and tumour cells and **lymphokine production**. The regulatory functions are either to increase or to suppress other lymphocytes and accessory cells.

Types of T-cells and their Functions

1. Helper T cells (T_H).

T_H cells are most numerous of the T cells. They help in the functions of immune system. They produce a growth factor that stimulates B-cell proliferation and differentiation and also stimulates antibody production by plasma cells; enhance activity of cytotoxic T cells.

2. Cytotoxic T cells (T_C) or Killer cells.

These cells are capable of killing microorganisms and even some of the body's own cells directly hence they are called **killer cells**. The **antigen receptors** on the surfaces of the cytotoxic cells cause specific binding with **antigens** present on the surface of foreign cell.

Cell after binding, the cytotoxic T cell secretes *hole-forming proteins*, called **perforins**, that punch large round holes in the membrane of the foreign cell. Then fluid flows quickly into the cell from the intestinal space. In addition, the cytotoxic T cell releases cytotoxic substances directly into the foreign cell. Almost immediately, the foreign cell becomes greatly swollen and it usually dissolves shortly thereafter.

Thus they destroy body cells infected by viruses and attack and kill bacteria, fungi, parasites and cancer cells.

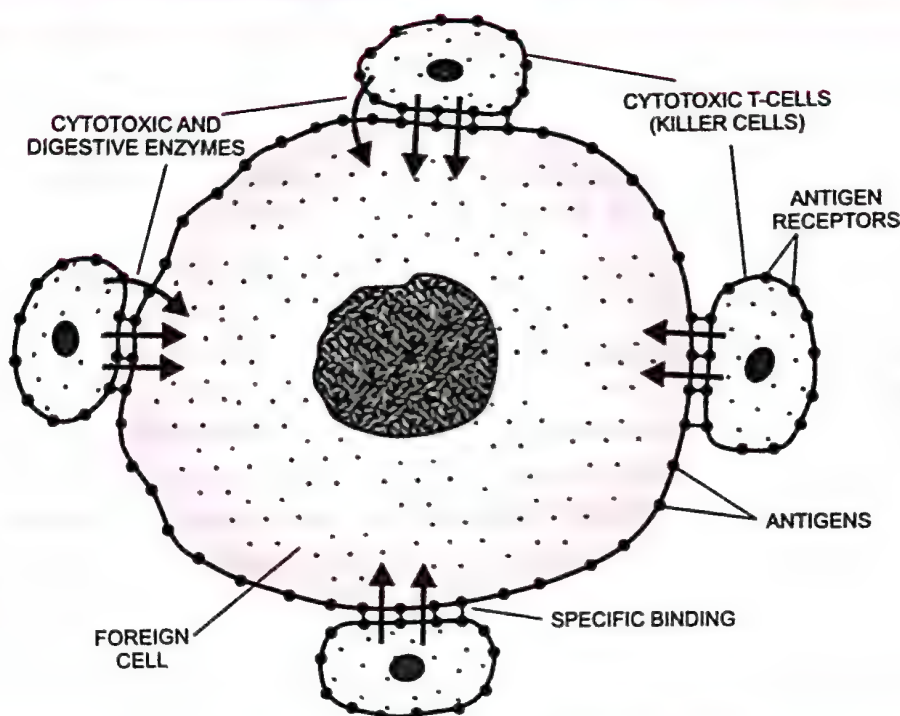


Fig. 8.9. Killing of a foreign cell by cytotoxic T-cells.

3. Memory T Cells (Primed Cells)

These cells are also formed by T-lymphocytes as a result of exposure to antigen and remain in the lymphatic tissue (e.g., spleen, lymph nodes). They recognize original invading antigens even years after the first encounter. These cells keep ready to attack as soon as the same pathogens infect the body again. They proliferate and differentiate into cytotoxic T cells, helper T cells, suppressor T cells, and additional memory cells.

4. Suppressor Cells (Regulatory T cells (T_R))

These cells are capable of suppressing the functions of cytotoxic and helper T cells. They also inhibit the immune system from attacking the body's own cells. It is believed that suppressor cells regulate the activities of the other cells. For this reason, the suppressor cells are classified as **regulatory T cells**.

Natural Killer (NK) Cells. NK cells attack and destroy target cells, participate in antibody dependent cell mediated cytotoxicity. They can also attack parasites which are much larger than bacteria.

POST – MENDELIAN DISCOVERIES

(Genetic Principles Discovered After Mendel)

GENE INTERACTION

Gene interaction is the influence of one allele over another of the same or other gene. It is of two types, **interallelic (intragenic)** and **nonallelic (intergenic)**. In the interallelic interaction the influence of one allele over another allele of the same gene, e.g., incomplete dominance, codominance, multiple alleles, lethal genes. In nonallelic interaction, allele of one gene influences the expression of another gene, e.g., epistasis, duplicate genes, complementary genes, supplementary genes.

INTERALLELIC (INTRAGENIC) INTERACTION

Incomplete Dominance (Intermediate Inheritance, 1 : 2 : 1 Ratio)

Incomplete dominance is the phenomenon where none of the two alleles of a gene is dominant over each other so that when both of them are present together, a new phenotype is formed which is somewhat intermediate between the independent expression of the two alleles.

It is also called mosaic or intermediate or blending inheritance. Incomplete dominance was discovered by **Carl Correns** in 1903. Incomplete or mosaic inheritance is not an example of pre-mendelian concept of blending inheritance because the parental types reappear in the F_2 generation. It is however, considered by some workers to be an example of quantitative inheritance where only a single gene pair is involved. F_2 phenotypic ratio is 1:2: 1, similar to genotypic ratio.

Examples. (i) Flower colour in Snapdragon and Four O'Clock. In *Antirrhinum majus* (Snapdragon or Dog flower) and *Mirabilis jalapa* (Four O' Clock), there are two types of flower colour in pure state, red and white. When the two types of plants are crossed, the hybrids or plants of F_1 generation have pink flowers (Figs. 5.16 & 5.17). If the latter are selfed, the plants of F_2 generation are of three types— red, pink and white flowered in the ratio of 1 : 2 : 1. The pink colour apparently appears either due to

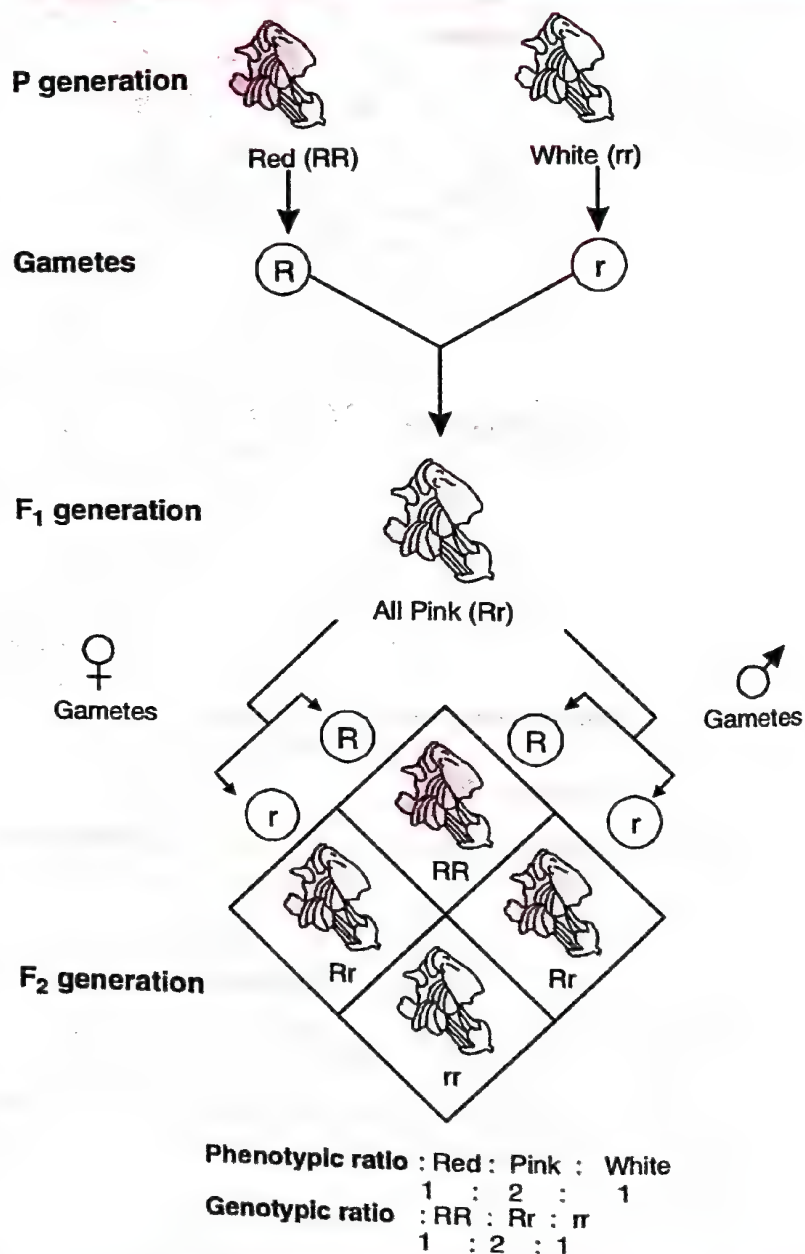


Fig. 5.16. Incomplete dominance in *Snapdragon*.

Types of Acquired Immunity

Acquired (= Adaptive) Immunity is of two types : active immunity and passive immunity.

1. **Active Immunity.** In this immunity person's own cells produce antibodies in response to infection or vaccination. It is slow and takes time in the formation of antibodies. It is long lasting and is harmless. Active immunity may be natural or artificial.

(a) A person who has recovered from an attack of *small pox* or measles or mumps develops **natural active immunity**.

(b) **Artificial active immunity** is the resistance induced by *vaccines*. Examples of vaccines are as follows: **Bacterial vaccines.** (a) Live– BCG vaccine for tuberculosis. (b) **Killed vaccines**– TAB vaccine for enteric fever. **Viral vaccines.** (a) **Live** – sabin vaccine for poliomyelitis, MMR vaccine for measles, mumps, rubella. (b) **Killed vaccines**– salk vaccine for poliomyelitis, neural and non-neural vaccines for rabies. **Bacterial products.** Toxoids for Diphtheria and Tetanus.

2. **Passive Immunity.** When ready-made antibodies are directly injected into a person to protect the body against foreign agents, it is called **passive immunity**. It provides immediate relief. It is not long lasting. It may create problems. Passive immunity may be natural or artificial.

(a) **Natural passive immunity** is the resistance passively transferred *from the mother to the foetus through placenta*. IgG antibodies can cross placental barrier to reach the foetus. After birth, immunoglobulins are passed to the newborn through the breast milk. Human **colostrum** (mother's first milk) is rich in IgA antibodies. Mother's milk contains antibodies which protect the infant properly by the age of three months.

(b) **Artificial passive immunity** is the resistance passively transferred to a recipient by administration of antibodies. This is done by *administration of hyperimmune sera of man or animals*. Serum (pl. sera) contains antibodies. For example, anti-tetanus serum (ATS) is prepared in horses by active immunisation of horses with tetanus toxoid, bleeding them and separating the serum. ATS is used for passive immunisation against tetanus. Similarly antidiphtheric serum (ADS) and anti-gas gangrene serum (AGS) are also prepared.

Differences between Active Immunity and Passive Immunity

Active Immunity	Passive Immunity
<ol style="list-style-type: none"> 1. It is developed when the person's own cells produce antibodies in response to infection or vaccine. 2. It provides relief only after long period. 3. It has no side effects. 4. It is long lasting. 	<ol style="list-style-type: none"> 1. It is developed when antibodies produced in other organisms are injected into a person to counter act antigen such as snake venom. 2. It provides immediate relief. 3. It may cause reaction. 4. It is not long lasting.

Immune Response

The **immune response** involves primary immune response and secondary immune response.

(a) **The primary immune response.** After an initial contact with an antigen, no antibodies are present for a period of several days. Then, a slow rise in the antibody titer

(arbitrary units) occurs, first IgM and then IgG, followed by a gradual decline in antibody titer. This is called the **primary immune response**.

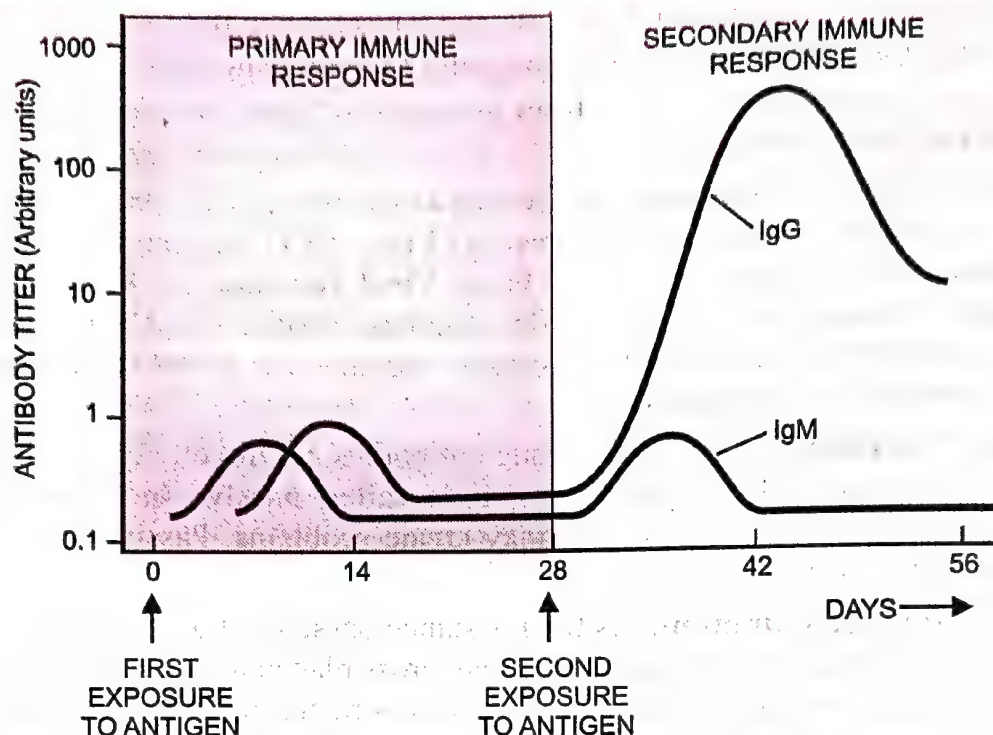


Fig. 8.10. Production of antibodies in the primary and secondary responses to a given antigen.

(b) **The secondary immune response.** Memory cells may remain in the body for decades. Every new encounter with the same antigen results in a rapid proliferation of memory cells. This is also called “**booster response**”. The antibody titer after subsequent encounters is far greater than during a primary response and consists mainly of IgG antibodies. This accelerated, more intense response is called the **secondary immune response**. Antibodies produced during a secondary response have an even higher affinity for the antigen.

A person who had been suffering from diseases like measles, small pox or chicken pox becomes immune to subsequent attacks of these diseases. It includes spleen, lymph nodes, tonsils, Peyer’s patches of small intestine and appendix.

The increased power and duration of the secondary immune response explain why **immunization** (method of providing immunity artificially, it is called vaccination) is usually accomplished by injecting antigen in multiple doses.

Differences between Primary Immune Response and Secondary Immune Response

Primary Immune Response	Secondary Immune Response
1. This immune response occurs as a result of the first contact with an antigen.	1. This immune response occurs at the second and subsequent exposure of the same antigen.
2. It takes longer time to establish immunity.	2. It is more rapid.
3. It declines rapidly.	3. It lasts for longer periods.

Lines of Defence

There are three lines of defence in the body.

- (1) **First Line of Defence.** It includes (i) Physical barriers, (ii) Physiological barriers.
- (2) **Second Line of Defence.** It comprises (i) Cellular barriers, (ii) Cytokine barriers.
- (3) **Third Line of Defence.** It includes acquired (adaptive) Immunity.

Antigens (Gk. *anti* – against, *genos*– birth)

Definition. Antigens are substances which, when introduced into the body, stimulate the production of antibodies.

Chemical Nature. Antigens consist of proteins, polysaccharides or nucleic acids.

Structure. Antigenic determinants or epitopes (Gk. *epi* – upon, *topos*– place) are components of antigen. Each antigen carries many epitopes. Each Y-shaped antibody molecule has atleast two binding sites that can attach to a specific epitope on an antigen. An antibody can also bind to identical epitopes of two different cells at the same time which can cause neighbouring cells to aggregate. Antigens combine with the antibodies. The combination is very much like the lock and key analogy.

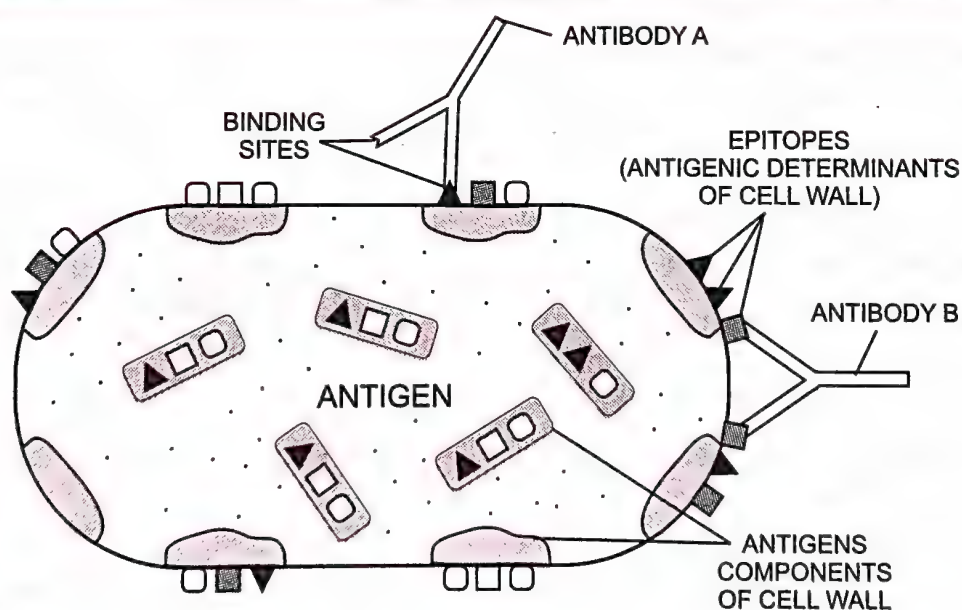


Fig. 8.11. Diagram showing an antigen with epitopes (antigenic determinants). Two attached antibodies are also shown.\

Types. Based upon the ability of antigens to carry out their functions, antigens are of two types: complete antigens and incomplete antigens (haptens). A **complete antigen** is able to induce antibody formation and produce a specific and observable reaction with the antibody so produced. **Haptens** (Gr. *haptēn* to grasp; **partial antigens**) are substances which are incapable of inducing antibody formation by themselves, but can be capable of inducing antibodies on combining with larger molecules (normally proteins) which serve as carriers.

Antigens which are present on the body's own cells are called the autoantigens or **self antigens**. The antigens on the nonself cells are known as foreign antigens or **nonself antigens**.

H antigen. Red blood corpuscles of all ABO blood groups possess a common antigen, the **H antigen**, which is a precursor for the formation of A and B antigens. Due to universal distribution, H antigen is not ordinarily important in grouping or blood transfusion. However, Bhende *et al* (1952) from Mumbai reported a very rare example in which A and B antigens and H antigens were absent from the red blood corpuscles. This is known as Bombay or Oh blood group. Such individuals will have anti A, anti B and anti H antibodies. Therefore, they can accept the blood only from their own group.

Antigen Presenting Cells (APCs)

The cells that can engulf antigens and present fragments to T cells are called antigen presenting cells (APCs).

There are three types of antigen presenting cells in the body : macrophages, dendritic cells and B cells.

1. **Macrophages.** Macrophages are usually found in a resting state. Their phagocytic capabilities are greatly increased when they are stimulated to become activated macrophages. The macrophages are present alongwith lymphocytes in almost all the lymphoid tissues, *e.g.*, *monocytes* as blood macrophages and *histocytes* as tissue macrophages.

2. **Dendritic Cells.** These cells are characterized by long cytoplasmic processes. Their primary role is to function as highly effective antigen-trapping and antigen presenting cells. These cells are nonphagocytic in nature. They are found in lymph nodes, spleen, thymus and skin. The different types of dendritic cells are :

(i) Langerhan's dendritic cells in epidermis of skin which trap the organisms coming in contact with body surface.

(ii) Dendritic cells in spleen, which trap the antigen in blood.

(iii) Follicular dendritic cells in lymph nodes which trap the antigen in the lymph.

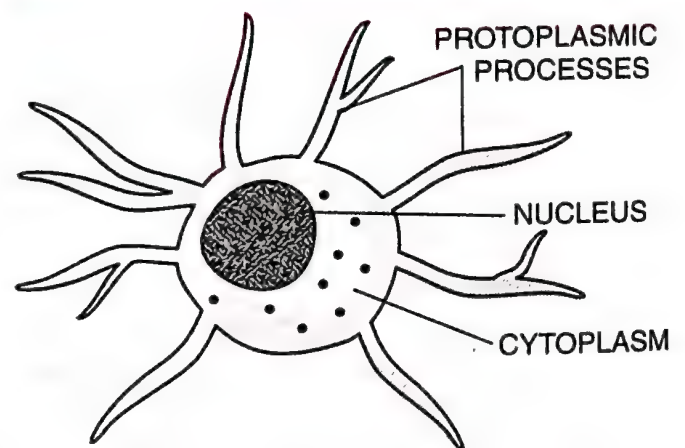


Fig. 8.12. Dendritic Cell.

Thus macrophages and dendritic cells play an important role in the trapping and presentation of antigens to T and B cells to initiate the immune response.

Steinman was awarded Nobel Prize (2011) for his discovery of the dendritic cell and its role in adaptive immunity.

3. **B-cells.** B-cells express on their surface intramembrane immunoglobulin (Ig) molecules that function as B cell antigen receptors. Since all the receptors on a single B cell are identical, each B cell can bind only one antigen. This makes them much more efficient antigen-presenting cells than macrophages, which must ingest any foreign material that comes their way.

Descendants of B-cells (plasma cells) produce antibodies.

Antibodies (Gk. *anti-* – against, *body* – body)

Definition. Antibodies are **immunoglobulins** (Igs) which are produced in the body in response to the antigen or foreign bodies. Thus all antibodies are immunoglobulins but all immunoglobulins are not antibodies.

Location and Formation. The antibodies may be bound to a cell membrane or they may remain free. Antibodies are produced by B lymphocytes and plasma cells. In fact B-lymphocytes get transformed into plasma cells. The mature plasma cell produces antibodies at an extremely rapid rate— about 2000 molecules per second. Antibodies direct the antibody-mediated immunity (= humoral immunity).

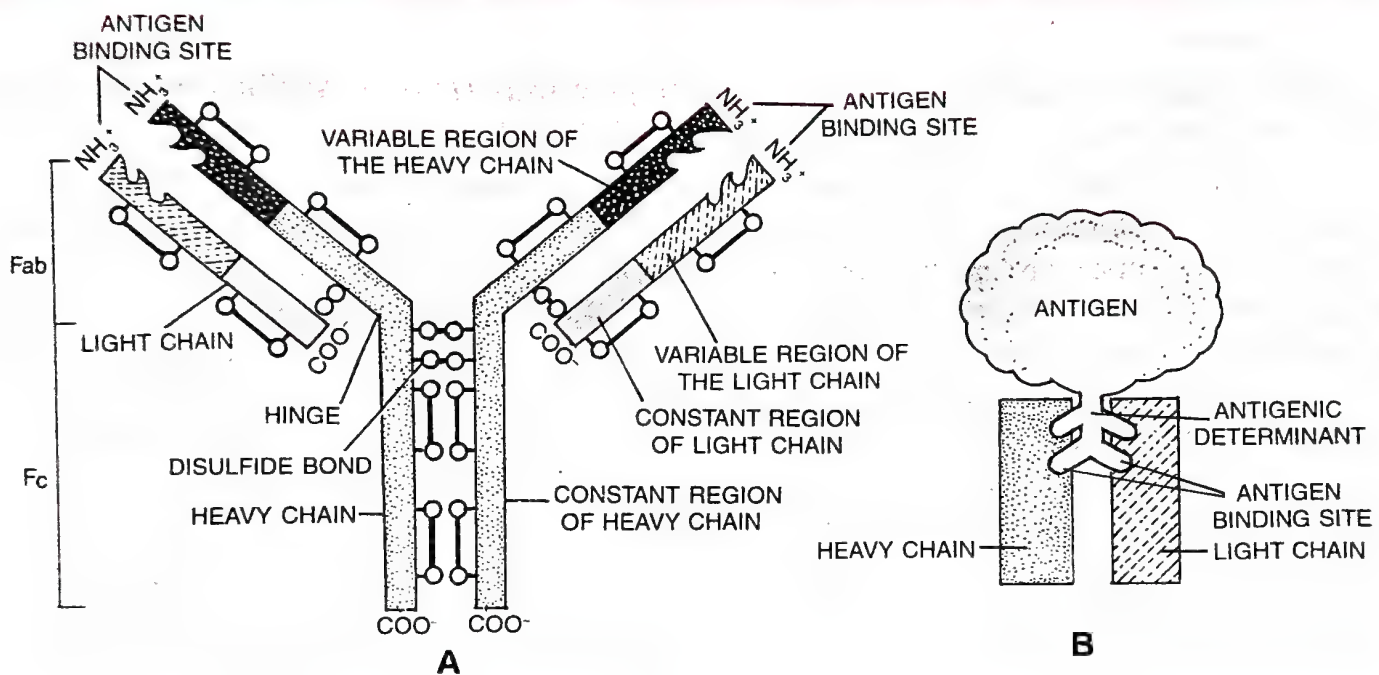


Fig. 8.13. A, structure of an antibody molecule. B, Antigen binding site.

Types of Antibodies. There are five types of antibodies viz :

1. IgA (Ig alpha); 2. IgD (Ig delta); 3. IgE (Ig epsilon); 4. IgG (Ig gamma) and 5. IgM (Ig mu).

Among the antibodies, IgG forms 80% of the antibodies in the body.

Antibody Structure. IgG has been studied extensively and serves as a model of basic structural unit of all Igs.

An antibody molecule consists of the following parts.

(i) **Heavy and Light Chains.** An antibody molecule is made up of 4 peptide chains, two small called **light chains** and two longer called **heavy chains**. Hence an antibody is represented as H₂L₂. The heavy chain has larger number of aminoacids while light chain has smaller number of aminoacids. Heavy and light chains may be either **lambda** or **Kappa** type.

(ii) **Constant and Variable Regions.** There are two different regions the **constant region** and **variable region** in each chain of the antibody.

(iii) **Disulfide Bonds and Hinge Region.** A disulfide bond joins a light chain with a heavy chain. Two disulfide bonds also link the two heavy chains. This part of the antibody displays considerable flexibility and is called the **hinge region**. Because the antibody "arms" can move somewhat as the hinge region bends, an antibody can assume a Y shaped molecule.

(iv) **Fragment Antigen Binding (Fab) and Fragment Crystallizable (Fc).** Two identical fragments of Y-shaped molecule possess the antigen-binding sites and are thus named *fragment-antigen binding (Fab)*. The antigen-binding sites bind to the specific antigens in a lock and key pattern, forming an **antigen-antibody complex**. The third fragment which lacks the ability to bind to antigen and can be crystallized, is, therefore, known as *fragment crystallizable (Fc)*.

The stem of the Y-shaped antibody monomer is called the F_C region, so named because when antibody structure was first being identified, it was a fragment (F) that crystallized (c) in cold storage.

Characteristics and Functions of Immunoglobulins (Igs) or Antibodies. Antibodies show the following characteristics and perform different functions.

(i) **IgA.** It is the *second most abundant class*, constituting about 10 to 15 per cent of antibodies of serum. It is mainly found in sweat, tears, saliva, mucus, **colostrum** (first milk secreted by a mother) and gastrointestinal secretions. Smaller quantities are present in blood and lymph. IgA has an extra polypeptide called a **J-(joining) chain** and extra protein known as **secretory component**. Levels decrease during stress, lowering resistance to infection. Provides localized protection in external secretions (tears, intestinal secretions, etc.) against bacteria and viruses. When IgA is excreted through faeces, it is called **coproantibody**.

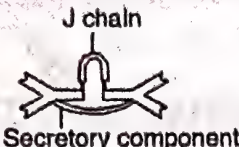



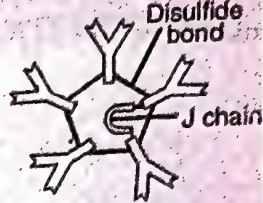
(ii) **IgD.** It is mainly found on the surfaces of B cells as antigen receptors, where it activates B cells for antigen recognition. It is about 0.2% of all antibodies in the blood.

(iii) **IgE.** It is less than 0.1% of all antibodies in the blood; located on mast cells and basophils releasing histamine from mast cells and basophils. It is involved in allergic and hypersensitivity reactions; provides protection against parasitic worms. This immunoglobulin was discovered in 1966 by **Ishizaka**. It exhibits unique properties such as heat lability (inactivated at 56°C in one hour). IgE mediates type I hypersensitivity (anaphylaxis). **Prausnitz** and **Kustner** demonstrated transmission of IgE-mediated type I hypersensitivity. It is called **Prausnitz-Kustner (PK) reaction**. Thus *IgE* acts as *mediator in allergic response*.

(iv) **IgG.** This is the *most abundant class of Ig* in the body constituting approximately 80% of the total Igs. It is found in the blood, lymph and intestine. It protects against bacteria and viruses by enhancing phagocytosis, neutralizing toxins and *complement activation*. It is the only class of antibody to cross the placenta from mother to foetus thereby conferring considerable immune protection in newborns.

(v) **IgM.** IgM is about 5 to 10% of all antibodies in the blood. It is also found in lymph. It is the *largest Ig* which is secreted first by the plasma cells. It is so named because it is a macroglobulin atleast five times larger than IgG. IgM is the oldest immunoglobulin class. It activates the B cells. It is also *the earliest immunoglobulin to be synthesised by the foetus*. IgM has a J chain and its each dimer contains polypeptide called a **secretory component**. It cannot cross the placental barrier. IgM is 500–1000 times more effective than IgG in opsonisation (to be described ahead), in bacterial action and in bacterial agglutination. But in neutralization of toxins and viruses, it is less active than IgG. It helps in complement activation.

Summary of Human Immunoglobulins (Antibodies)

Characteristics	IgA	IgD	IgE	IgG	IgM
					
Structure	Dimer (with secretory component) and J-chain	Monomer	Monomer	Monomer	Pentamer with J chain
Percentage of total serum antibody	10–15%	0.2%	Less than 0.1%	80%	5–10%
Location	Secretions (tears, saliva, mucus, intestine, colostrum), blood, lymph	B cell surface, blood, lymph	Bound to mast and basophil cells throughout body, blood	Blood, lymph, intestine	Blood, lymph, B cell surface (as monomer)
Function	Localized protection in external secretions (tears, intestinal secretions, etc.)	Antigen recognition by B cells	it is involved in allergic reactions	Complement activation	Complement activation
Placental transfer	No	No	No	Yes	No

Monoclonal Antibodies (MAbs)

Production. 1. A mouse is injected with a specific antigen that will induce antibodies against that antigen.

2. The spleen of the mouse is removed and a suspension is made. The suspension includes **B cells** that produce antibodies against the injected antigen.

3. The spleen cells are then mixed with **myeloma cells** (cancer cells) that are capable of continuous growth in culture but have lost the ability to produce antibodies. Some of the antibody-producing spleen cells and myeloma cells fuse to form hybrid cells. These hybrid cells are now capable of growing continuously in culture while producing antibodies.

4. The mixture of cells is placed in a selective medium that allows only hybrid cells to grow.

5. **Hybrid cells** proliferate into clones called **hybridomas**. The hybridomas are screened for production of the desired antibody.

6. The selected hybridomas are then cultured to produce large quantities of **monoclonal antibodies (MAbs)** because they come from a single clone of identical cells.

Who described Method of Production ? The method of production of **monoclonal antibodies (MAbs)** was described by **Jerne, Kohler and Milstein** in 1975 for which they were awarded Nobel Prize for medicine in 1984.

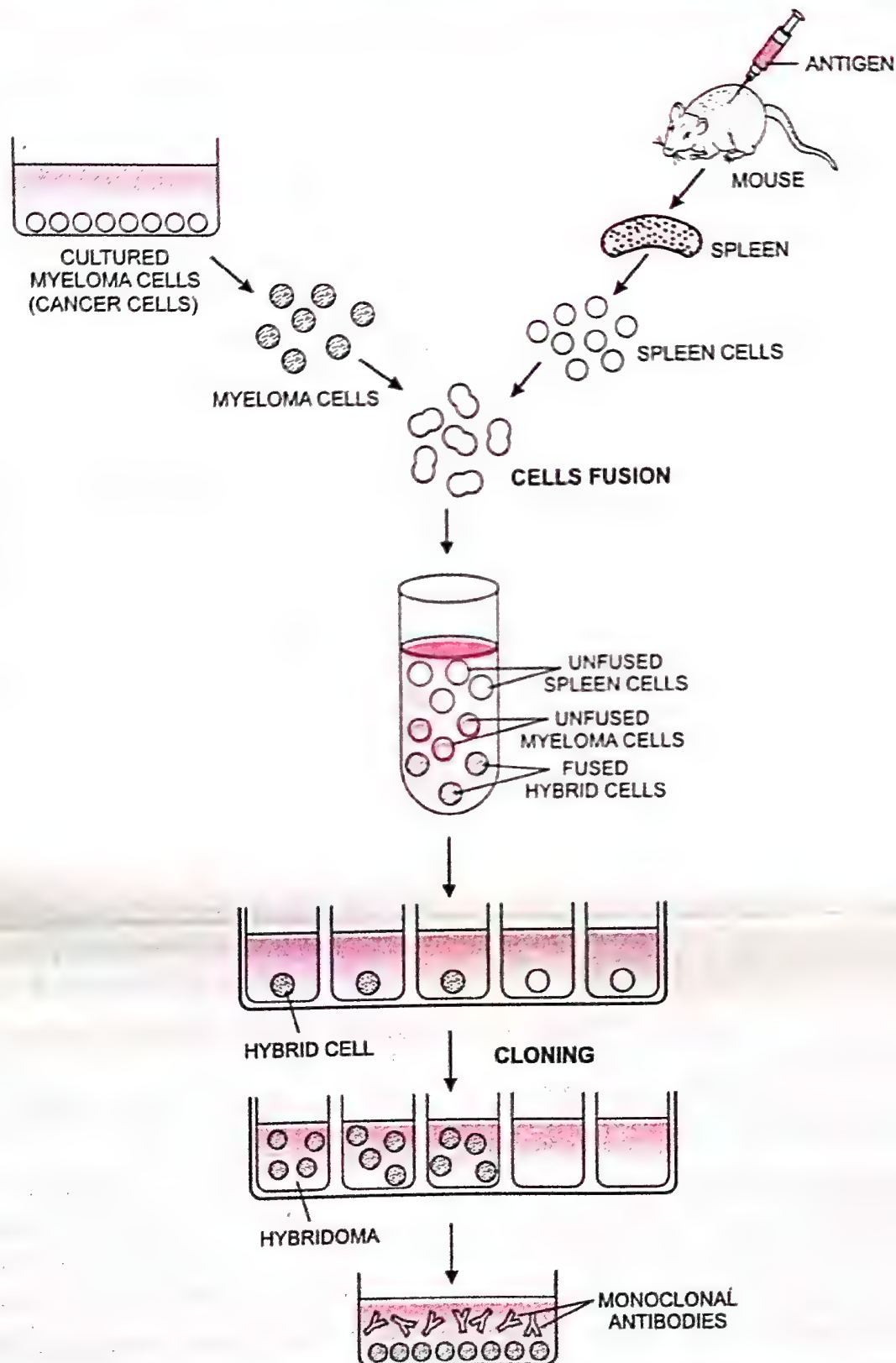


Fig. 8.14. The production of monoclonal antibodies.

Uses of monoclonal antibodies include the following. They recognize several bacterial pathogens, diagnosis of pregnancy, allergies and diseases such as hepatitis, rabies and some

sexually transmitted diseases. MAbs have also been used to detect cancer at an early stage and to know the extent of metastasis. MAbs are also being used since 1986 to minimize rejection of kidney transplants. For these purposes MAbs are prepared that react with the T cells that are responsible for rejection of the transplanted tissue. The MAbs suppress the T cell activity. They may also be used to treat autoimmune diseases.

Formation of Antigen-Antibody Complex (Antibody Action)

Epitopes (antigenic determinants) are components of the antigen, *e.g.*, the bacterial cell wall. Each antigen carries more than one epitope. Each Y-shaped antibody molecule has at least two binding sites that can attach to a specific epitope on an antigen. An antibody can also bind to identical epitopes on two different cells at the same time which can cause neighbouring cells to aggregate.

The antibodies can inactivate the invading agent in one of different ways, as given below.

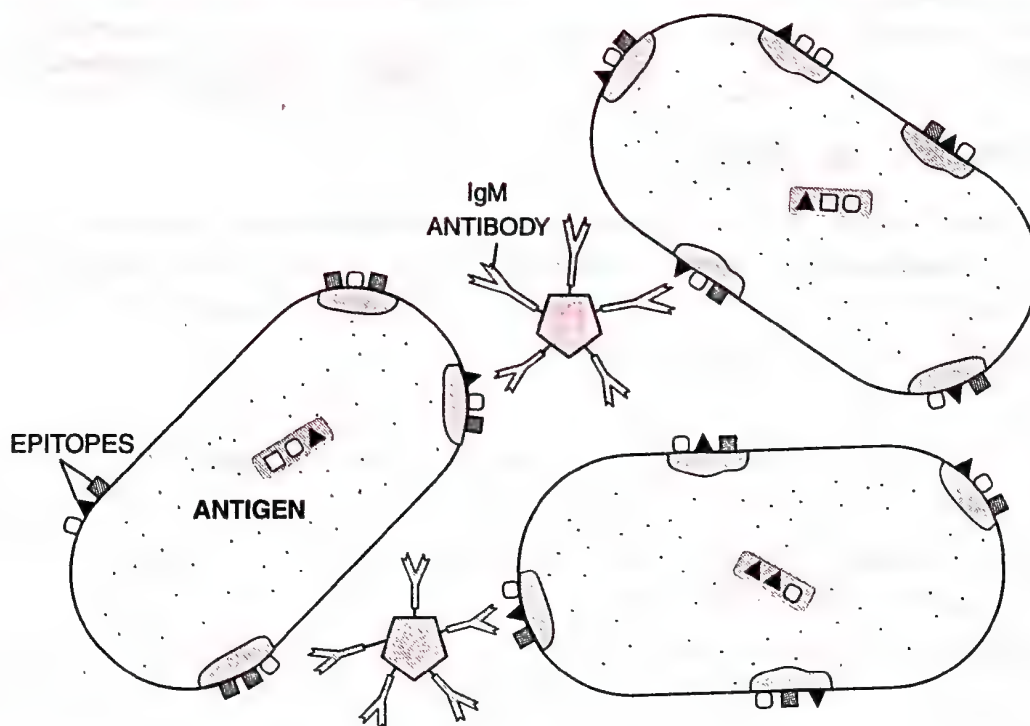


Fig. 8.15. Agglutination of antigen molecules to one another by bivalent antibodies.

1. **Agglutination.** Clumping of microorganisms or blood cells, typically due to an antigen-antibody reaction is called **agglutination**.

2. **Opsonization (Adherence).** For opsonization (Gr. *opsonare*, meaning to cater) the antigen, such as a bacterium is coated with antibodies that enhance phagocytosis. Making microbes more susceptible to phagocytosis is known as opsonization. These antibodies are called **opsonins**.

3. **Precipitation.** Phagocytic cells ingest agglutinated microbes more readily. Likewise, soluble antigens may come out of solution and form a more easily phagocytized precipitate when cross-linked by antibodies. This process is called **precipitation**.

4. **Neutralization.** The reaction of antibody with antigen blocks or neutralizes some

bacterial toxins and prevents attachment of some viruses to body cells. This is called **neutralization**.

5. **Lysis**. Some powerful antibodies attack plasma membrane of the cell and thereby causing rupture of the plasma membrane allowing escape of the cell contents is called **lysis** (Gr.- dissolution).

These direct actions of antibodies attack the antigenic invaders.

Differences between Antibodies and Antigens	
<i>Antibodies (Immunoglobulins)</i>	<i>Antigens (Immunogens)</i>
1. Antibody is a protein molecule.	1. Antigen is a protein or polysaccharide molecule.
2. It is synthesized by an animal to combat foreign material.	2. It is usually a foreign material that stimulates antibody formation.
3. Antibody occurs on the surface of a plasma cell and also in body fluids.	3. Antigen may occur on the surface of a microbe or as a free molecule.
4. Antibody directly joins an antigen to destroy the latter.	4. Antigen binds to a macrophage to reach a helper T-cell to initiate immune response.

Immune System in the Body

The human immune system consists of **lymphoid organs**, **tissues cells** and soluble molecules like **antibodies**. Immune system recognises foreign antigens, responds to these and remembers them. This system also plays an important role in allergic reactions, autoimmune diseases and organ transplantation.

Lymphoid Organs

Lymphoid organs are those organs where the maturation and proliferation of lymphocytes takes place.

Types of Lymphoid organs. There are two types of lymphoid organs: primary lymphoid organs and secondary lymphoid organs.

1. **Primary lymphoid organs.** The primary lymphoid organs are those organs where T lymphocytes and B lymphocytes, mature and acquire their antigen-specific receptors. After maturation, the lymphocytes migrate to secondary lymphoid organs. Primary lymphoid organs include **bone marrow** and **thymus**.

(i) **Bone marrow.** Bone marrow is the main lymphoid organ where all blood cells including lymphocytes are formed. Maturation of B-lymphocytes occurs here.

(ii) **Thymus.** Thymus is the site of T lymphocyte maturation. Thymus is situated near the heart. Thymus is quite large in size at the time of birth but keeps reducing with age. As stated earlier, T-lymphocytes and B-lymphocytes are responsible for cellular and humoral immune response respectively.

2. **Secondary lymphoid organs.** After maturation, B lymphocytes and T lymphocytes migrate via blood vascular and lymphatic system to the secondary lymphoid organs where they undergo proliferation and differentiation. The acquired immune response to antigens usually develops in these organs and becomes effector cells. In the secondary lymphoid tissues, the lymphocytes do not remain, and move from one lymphoid organ to another through blood and lymph. The secondary lymphoid organs are lymph nodes, spleen, tonsils, Peyer's patches of the small intestine and mucosal associated lymphoid tissues (MALT).

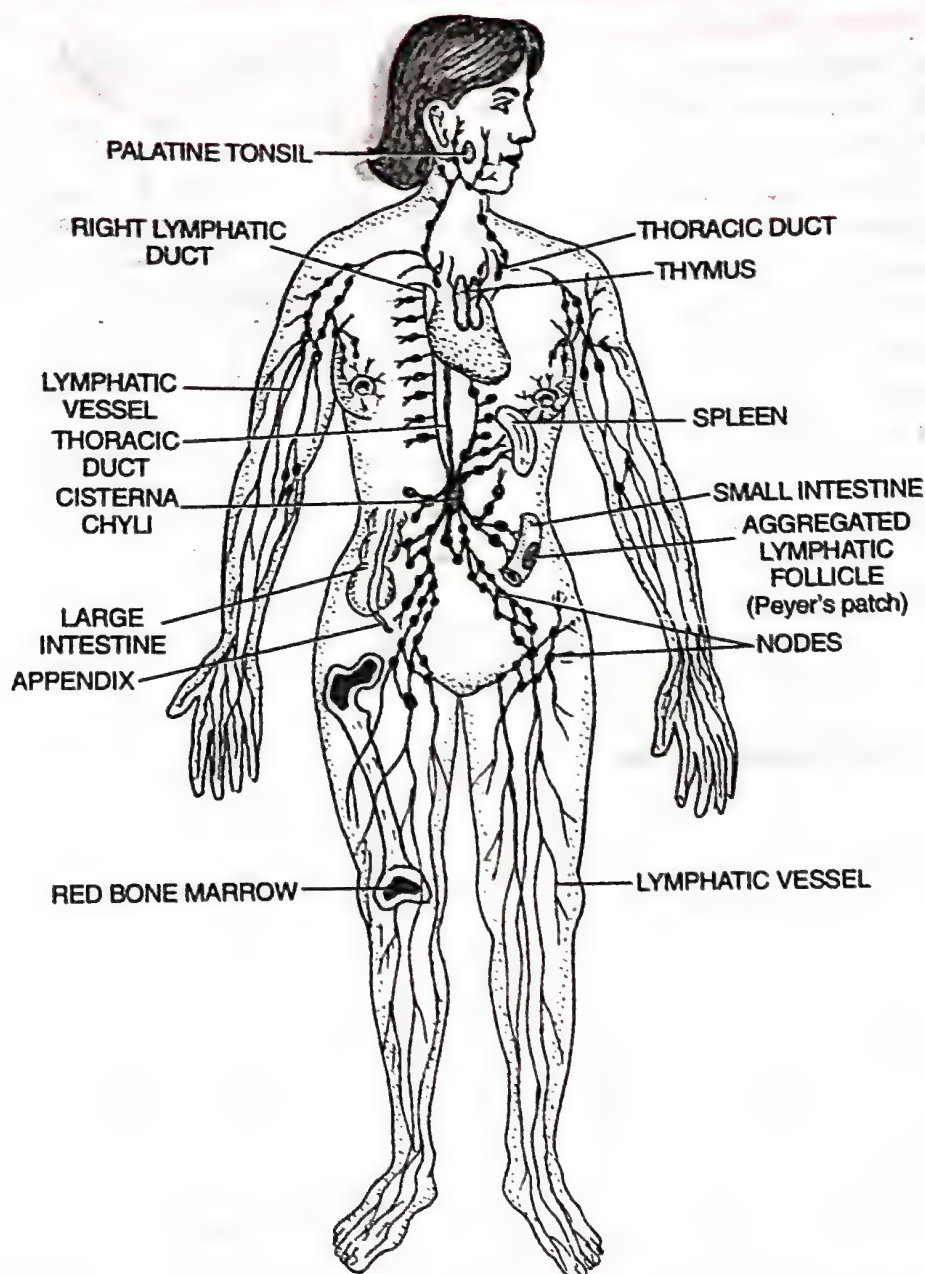


Fig. 8.16. Anterior view of principal components of Human Lymphatic System.

(i) **Lymph nodes.** These are small solid structures found at intervals along the lymphatic system. They are composed of lymphoid tissue and act as filters for the lymph, preventing foreign particles from entering the bloodstream. Lymph nodes also produce lymphocytes and plasma cells.

(ii) **Spleen.** It is a bean shaped organ which is the **largest** single mass of lymphoid tissue in the body. In foetus the spleen produces all types of blood cells but in adult it only produces lymphocytes. Macrophages of spleen are phagocytic.

(iii) **Tonsils.** Usually there are six tonsils. They act as filters to protect body from bacteria and aid in the formation of white blood cells.

(iv) **Peyer's patches.** These are clusters of lymph nodules found in small intestine, especially along the ileum. They produce lymphocytes.

carrying these genes die. They are lost in the same generation. **Examples.** (a) Lethal gene was first discovered by Cuenot (1905) in mouse body colour. (b) **Brachyphalangy** (short fingers) in humans. (c) Inheritance of **sickle-cell anaemia** in man. (d) **Huntington's Chorea in man** (the person suffers from muscular failure, mental retardation and finally death).

(ii) **Recessive Lethal Genes.** The recessive lethal genes produce lethal effect only in homozygous condition. Their heterozygotes are normal. Recessive lethal genes are carried in heterozygous condition. **Examples.** (a) **Tay Sach's disease** — accumulation of fat in nerve sheaths hampers transmission of nerve impulse leading to poor muscular control and mental deficiency. (b) **Hydrocephaly in mice** — irregularly formed skull and brain and accumulation of cerebrospinal fluid. (c) **Albinism in corn** — A lethal gene in corn. The non-chlorophyll plants are unable to manufacture their own food and will die as soon as food stored in the grain has been consumed.

(iii) **Conditional Lethal Genes.** The genes which may be normal to the individual in a particular environment may prove to be lethal when environment is changed. **Example.** In **poultry** a recessive gene causes feathers to break off. The chickens homozygous for this gene are featherless. If these are kept in relatively warm environment, they survive but if temperature falls below optimum, the featherless chickens die.

- Soon after Cuenot's discovery in mouse, **E. Baur** (1907) reported a lethal gene in Snapdragon, *Antirrhinum majus*.

- **Thalassemia major** is also one of the best known example of lethal genes. This disease of humans is characterized by severe anaemia, enlargement of the heart, leg ulcers, etc.

NONALLELIC (INTERGENIC) INTERACTIONS

Alleles of two or more independent genes interact to produce a phenotypic expression different from normal expression.

Salient Features of Nonallelic (Intergenic) Gene Interaction

The characteristics of such nonallelic interactions are as follows.

1. Interaction produces a distinct phenotype different from the normal.
2. Interacting genes show normal dominance-recessiveness and assort independently.
3. At phenotypic level, homozygotes and heterozygotes, such as AA or Aa and BB or Bb show their respective phenotypes governed by the dominant alleles. They are designated as A- or B-, where a dash indicates the presence of either allele.
4. The F_1 individuals are heterozygous for the various gene pairs (Aa Bb) which will be selfed or intercrossed.
5. In a normal dihybrid cross, the F_2 genotypes fall into four phenotypic classes 9/16 A- B-, 3/16 A-bb, 3/16 aa B- and 1/16 aabb.

Epistasis

Epistasis (Gk. *epi* — above, *stasis* — standing) is the phenomenon of masking or suppressing the expression of a gene by another nonallelic gene. The gene which suppresses the expression of a nonallelic gene is known as **epistatic gene**. The gene or locus which is suppressed by the presence of nonallelic gene is termed as **hypostatic gene**. The phenomenon by which the effect of a gene gets suppressed due to the presence of a nonallelic gene is called **hypostasis**.

1. **Attenuated whole-agent vaccines** use living but attenuated (weakened) microbes. Examples of attenuated vaccines are the Sabin polio vaccine and those used against measles, mumps and rubella (MMR). The widely used vaccine against the tuberculosis bacillus and bacteria.

2. **Inactivated whole-agent vaccines** use microbes that have been killed. Inactivated virus vaccines used in humans include those against rabies, influenza and polio (the Salk polio vaccine). Inactivated bacterial vaccines include those for pneumococcal pneumonia, cholera, pertussis (whooping cough) and typhoid.

3. **Toxoids** which are inactivated toxins, are vaccines directed at the toxins produced by a pathogen. Examples. Vaccines against tetanus and diphtheria.

4. **Subunit vaccines** use only those antigenic fragments of a microorganism that best stimulate an immune response. Subunit vaccines that are produced by genetic modification techniques, meaning that other microbes are programmed to produce the desired antigenic fraction, are called **recombinant vaccines**. For example, the vaccine against the hepatitis B virus consists of a portion of the viral protein coat that is produced by a genetically modified yeast.

5. **Conjugated vaccines** have been developed in recent years to deal with the poor immune response of children. The polysaccharides are combined with proteins. This approach has led to the very successful vaccine for *Haemophilus influenzae* type b, which gives significant protection.

6. **Nucleic acid vaccines** or DNA vaccines are among the newest and most promising vaccines, although they have not yet resulted in any commercial vaccine for humans. Experiments with animals show that plasmids of "naked" DNA injected into muscle results in the production of the protein encoded in the DNA. (The "gene gun" method for injecting nucleic acids into plant cells is described in Chapter 11). These proteins stimulate an immune response. A problem with this type of vaccine is that the DNA remains effective only until it is degraded. Indications are that RNA, which could replicate in the recipient, might be a more effective agent.

Vaccines are also classified as follows.

1. **First generation vaccines.** These are produced by conventional methods, e.g., small pox vaccine, Salk's polio vaccine.

2. **Second generation vaccines.** These are prepared with the help of genetic engineering technique, e.g., vaccines against Hepatitis B, Herpes, Influenza and Rabies.

3. **Third generation vaccines.** These are synthetic vaccines which are under trial.

Vaccines under study. Vaccines against Malaria, Leprosy, Hepatitis C, AIDS, Dental caries, etc. are under study.

Immunisation and Pregnancy. The question of whether immunisation of a pregnant woman presents any danger for the foetus is frequently raised. Ideally, immunisation should be performed before gestation, since some vaccines are not perfectly safe during pregnancy. Pregnant women are however, often vaccinated either because they travel to foreign countries or when an epidemic occurs.

Vaccines which are safe during pregnancy are tetanus, influenza, inactivated poliomyelitis, cholera and hepatitis B.

Vaccines which are to be avoided during pregnancy are small pox vaccine, oral polio-myelitis vaccine and rubella vaccine.

Indian National Immunization Schedule

- | | |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (a) For infants | |
| At birth | - BCG and OPV-0 dose |
| (For institutional deliveries) | |
| At 6 weeks | - BCG (if not given at birth) |
| | - DPT-1, OPV-1 and Hepatitis B-1 |
| At 10 weeks | - DPT-2, OPV-2 and Hepatitis B-2 |
| At 14 weeks | - DPT-3, OPV-3 and Hepatitis B-3 |
| At 9 months | - Measles |
| (b) At 16-24 months | - DPT and OPV |
| (c) At 5 - 6 years | - DT (the second dose of Diphtheria toxoid should be given at an interval of one month if there is no clear history or documented evidence of previous immunization with DPT) |
| | - <i>Tetanus Toxoid</i> - The second dose of TT vaccine should be given at an interval of one month if there is no clear history or documented evidence of previous immunization with DPT, DT or TT vaccines |
| (d) At 10 and at 16 years | |
| (e) For Pregnant Women | |
| Early in pregnancy | - TT-1 or Booster |
| One month after TT-1 | - TT-2 |

- Note.**
- Interval between 2 doses of DPT, OPV and Hepatitis B should not be less than one month.
 - Minor cough, colds and mild fever are not a contraindication to vaccination.
 - In some states, Hepatitis B vaccine is given as routine immunization at 6th, 10th and 14th weeks.
 - Vitamin A is given at 9th, 18th, 24th, 30th and 36th month.
 - If the child has diarrhoea, give a dose of OPV, but do not count the dose and ask the mother to return in 4 weeks for the missing dose.

Disorders of Immune System

1. Allergies

Meaning. Allergy is the hypersensitiveness of a person to some foreign substance coming in contact with or entering the body.

Allergens. The substances that cause allergic reaction are called allergens. The common allergens are dust, pollen, mould, spores, fabrics, lipsticks, nail paints, feathers, fur, plants, bacteria, foods, heat, cold, sunlight.

Symptoms. The symptoms that result from an allergy may be of different kinds but mostly it affects

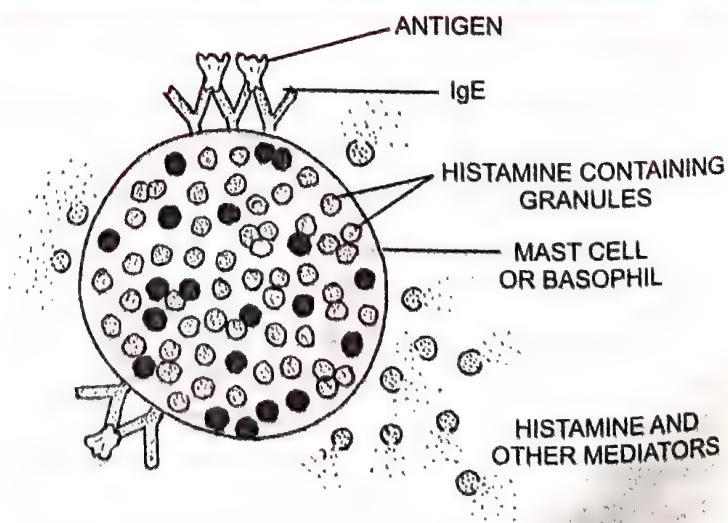


Fig. 8.18. IgE antibodies, produced in response to an antigen, coat mast cells and basophil.

the skin and mucous membrane. Symptoms of allergic reactions include sneezing, watery eyes, running nose and difficulty in breathing.

Cause. Allergy involves mainly IgE antibodies and chemicals like histamine and serotonin from the mast cells. IgE antibodies are produced in response to an antigen, coat mast cells and basophils. The allergic tendency is genetically passed from parent to child and is characterized by the presence of large quantities of IgE *antibodies* in the blood. These antibodies are called **sensitizing antibodies** to distinguish them from the more common IgG antibodies. First exposure to antigen causes primary immune response, but it does not cause allergy. When an *allergen* enters the body second time, it causes second immune response reaction and a subsequent allergic reaction occurs. It causes marked dilation of all the peripheral blood vessels and the capillaries become highly permeable so that large amounts of fluid leak out from the blood into the tissues. The blood pressure decreases drastically.

Some forms of allergy are mentioned below.

(i) **Hay Fever.** It is the form of allergy due to pollen of grasses, trees and other plants. It is characterized by inflammation of the membrane lining the nose and sometimes of the conjunctiva. The symptoms of sneezing, running or blocked nose and watering eyes due to histamine release often respond to the treatment with antihistamines.

(ii) **Asthma.** The tissue surrounding the bronchioles of the lungs swell up and compress the bronchioles. Hence there is difficulty in breathing. Administration of antihistamines has little effect on the course of asthma because histamine does not appear to be the major factor causing the asthmatic reaction. Treatment is with bronchodilators with or without corticosteroids, usually administered via aerosol or dry-powder inhalers. Avoidance of known allergens, especially the house dust mite, allergens arising from domestic pets and food additives will help to reduce the frequency of attacks as will the discouragement of smoking.

(iii) **Anaphylaxis (Anaphylactic shock).** It is an allergic reaction involving all the tissues of the body and occurs in a few minutes after the injection of an antigen such as **penicillin**. Such a reaction is very serious. Histamine released from ruptured mast cells causes marked dilation of all the arteries so that a large amount of fluid is passed from the blood to the tissues and there is a drastic fall in blood pressure. The affected person may become unconscious and the individual may die within a short time.

The use of drugs such as antihistamine, adrenalin and steroids quickly reduce the symptoms of allergy.

2. Autoimmunity

The unique property of the immune system is that it always destroys the foreign proteins but never attacks the body own proteins.

Definition. If the immune system fails to recognize 'self' from 'nonself' and starts destroying the body's own proteins, this leads to some malfunctions which are called autoimmune diseases. This immunity is known as autoimmunity.

Cause. Autoimmunity is caused due to the following.

Genetic Factors. Some individuals are genetically more susceptible to developing autoimmune diseases than others. This mostly happens when certain genes start showing abnormalities. These genes could be those of antibodies, T-cell receptors and MHC genes (major histocompatibility complex genes). Autoimmune disorders occur more in women than in men. Autoimmunity seems to run in some families.

Environmental Factors. Environment also plays some role in the induction of autoimmune diseases. Besides, autoimmune diseases can be manifested because of certain drugs, chemicals pesticides and toxins. The C-Reactive proteins (CRPs) are essential part of the immune system, which get elevated in almost all autoimmune disorders.

Increased helper T cell and decreased suppressor T cell functions have been suggested as causes of autoimmunity. Autoimmune diseases are caused by self-reacting antibodies.

Examples. Some important examples of autoimmune diseases are given below.

Some Autoimmune Diseases

Disease	Organ or Tissue	Signs and Symptoms
1. Addison's disease	Adrenal cortex	Undersecretion of adrenal cortex hormones; weakness, nausea, weight loss, low blood sodium, low blood volume and pressure, darkened skin pigmentation
2. Diabetes mellitus (type I)	Beta cells of pancreas	Undersecretion of insulin; high blood sugar
3. Graves' disease	Thyroid	Oversecretion of thyroid hormone; high metabolic rate
4. Autoimmune Haemolytic anaemia	Red blood cells (RBCs)	Destruction of RBCs; low RBC count; anaemia
5. Hashimoto's Thyroiditis	Thyroid	A firm swelling of thyroid gland and partial or total failure of secretion of thyroid hormones. More common in women
6. Multiple sclerosis	Myelin sheath around nerve cells	Loss of precise muscle control
7. Myasthenia gravis	Muscle	Muscular weakness and fatigue
8. Pernicious anaemia	Stomach cells; intrinsic factor	Low production of intrinsic factor required for absorption of vitamin B ₁₂ , a substance needed for RBC production; anaemia
9. Rheumatic fever	Heart cells; valves	Usually occurs after a <i>Streptococcal</i> bacteria infection of the throat. Rheumatic fever may weaken the entire heart wall, most often it damages the bicuspid (mitral) and aortic valves
10. Rheumatoid arthritis (RA)	Joints	Immune complexes of IgM, IgG and complement are deposited in the joints. Mutant IgM attacks IgG, inflaming joints, destroying articular cartilage and fusing bones
11. Systemic lupus erythematosus (SLE)	Kidney, brain, skin and other organ systems	Include joint pain, slight fever, oral ulcer, enlarged lymph nodes & spleen, more common in female

Possible Treatments. To control different types of autoimmune diseases, continuous attempts are being made to develop newer and advanced treatment options.

(1) **Use of Immunosuppressants.** Immunosuppressive drugs (*e.g.*, corticosteroids, azathioprine and cyclophosphamide) are often given to reduce the severity of the autoimmune disorders. But as this treatment suppresses the overall immune responses, the patients are at great risk of having cancer and other diseases.

(2) **Plasmapheresis.** In this line of treatment the plasma is first separated from the patient's blood by centrifugation. After removing the reactive autoantibodies from plasma, the blood is transfused back to the patient.

(3) **T-Cell Vaccination.** Vaccination using T-cells can be an effective means of treating autoimmune diseases.

(4) **Use of Monoclonal Antibodies.** Monoclonal antibodies have been successfully used in the treatment of autoimmune diseases.

(5) **Use of Stem Cells.** Adult haematopoietic stem cell transplantation can be done.

3. Immunodeficiency Diseases

Immunodeficiency diseases are conditions where the defence mechanisms of the body are weakened, leading to repeated microbial infections.

Types. Immunodeficiency diseases may be primary or secondary.

(i) **Primary Immunodeficiency Diseases.** These diseases exist from the birth. A person may be without B-cells or T-cells or both from the birth. Example. **Severe combined immunodeficiency disease (SCID).**

(ii) **Secondary Immunodeficiency Diseases.** A variety of factors such as malnutrition, infections, metabolic disorders, malignancy and cytotoxic drugs may lead to defects in specific and nonspecific immunity. Thus secondary immunodeficiency diseases are more common than primary deficiency diseases. Examples. AIDS and Hodgkin's disease (a malignant disease of lymphatic tissue— a form of lymphoma).

Differences between Autoimmune and Immunodeficiency Diseases	
<i>Autoimmune Diseases</i>	<i>Immunodeficiency Diseases</i>
<ol style="list-style-type: none"> 1. In autoimmune diseases immune system starts destroying the body's own proteins. 2. The body is protected from external pathogens 3. Self destruction occurs. 4. Examples. Addison's disease, Diabetes mellitus (type 1), Rheumatic fever and Hashimoto's thyroiditis. 	<ol style="list-style-type: none"> 1. In immunodeficiency diseases the defence mechanisms of the body become weak, leading to repeated microbial infection. 2. The body is not protected from pathogens. 3. There is slow destruction due to pathogen. 4. Examples. SCD & AIDS.

SCID— Severe Combined Immunodeficiency Disease

The person who is suffering from SCID lacks both B-cells and T-cells from birth. It is a serious genetic disease in which the person is highly susceptible to infection.

1. **Kernel Colour in Wheat.** As stated earlier Nilsson-Ehl (1908) first investigated the inheritance of kernel colour in wheat. He found that the kernel colour in wheat is determined by three pairs of genes.

2. **Human Skin Colour.** It was first studied by Davenport (1913) in case of Negro-caucasian intermarriages in Jamaica and Muda (Malayasia). Human skin colour is caused by pigment called **melanin**. The quantity of melanin is due to three pairs of polygenes (A, B and C). If black or very dark (AABBCC) and white or very light (aabbcc) individuals marry, the offspring or individuals of F_1 generation show intermediate colour often called **mulatto** (AaBbCc). When two such individuals of intermediate colour marry, the skin colour of the

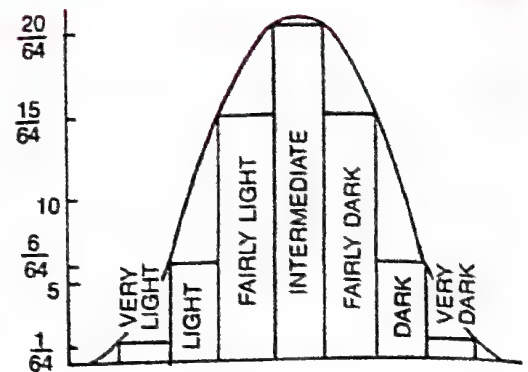


Fig. 5.28. Histogram and bell shaped curve produced from the frequency of various skin phenotypes produced in F_2 generation after a cross between black and white individuals.

		White aabbcc (very light)		Black AABBCC (very dark)		Parents			
		abc		ABC		Gametes			
		AaBbCc Intermediate						F ₁ generation	
Gametes →	ABC	aBC	AbC	ABc	abC	Abc	aBc	abc	
↓	ABC	AABBCC very dark	AaBBCC dark	AABbCC dark	AABBcc dark	AaBbCC fairly dark	AABbCc fairly dark	AaBBCC fairly dark	AaBbCc intermediate
	aBC	AaBBCC dark	aaBBCC fairly dark	AaBbCC fairly dark	AaBBcc fairly dark	aaBbCC intermediate	AaBbCc intermediate	aaBBCC intermediate	aaBbCc fairly light
	AbC	AABbCC dark	AaBbCC fairly dark	AABbCC fairly dark	AABbcc fairly dark	AabbCC intermediate	AabbCc intermediate	AaBbCc intermediate	AabbCc fairly light
	ABc	AABBCC dark	AaBBCC fairly dark	AABbCc fairly dark	AABBcc fairly dark	AaBbCc intermediate	AABbcc intermediate	AaBBcc intermediate	AaBbcc fairly light
	abC	AaBbCC fairly dark	aaBbCC intermediate	AabbCC intermediate	AaBbCc intermediate	aabbCC fairly light	AabbCc fairly light	aaBbCc fairly light	aabbCc light
	Abc	AABbCc fairly dark	AaBbCc intermediate	AABbCc intermediate	AABbcc intermediate	AabbCc fairly light	AABbcc fairly light	AaBbcc fairly light	Aabbcc light
	aBc	AaBBCC fairly dark	aaBBCC intermediate	AaBbCc intermediate	AaBBcc intermediate	aaBbCc fairly light	AaBbcc fairly light	aaBBcc fairly light	aaBbcc light
	abc	AaBbCc intermediate	aaBbCc fairly light	AabbCc fairly light	AaBbcc fairly light	aabbCc light	Aabbcc light	aaBbcc light	aabbcc very light

Phenotypes : Very Dark (Black)—1, Dark—6, Fairly Dark—15, Intermediate—20, Fairly Light—15, Light—6, Very Light (White)—1.

Fig. 5.29. Quantitative inheritance of Skin Colour in human beings.

Americans as **HCLV III** (Human cell leukemia virus III), but as stated earlier the name of the virus was changed to **HIV** (Human immunodeficiency virus). *HIV is a retrovirus that attacks helper T cells.*

Structure of HIV. The virus is spherical with a diameter of about 90–120 nm. Its genome consists of a single-stranded RNA filament segmented into two identical filaments and associated with a **reverse transcriptase enzyme**. The envelope consists of a lipid bilayer derived from host cell membrane and projecting knob like glycoprotein spikes. It contains two protein coats.

Mode of Action of AIDS Virus. After the entrance of the virus into the body of the person, the virus enters into macrophages where RNA genome of the virus replicates to form viral DNA with the help of reverse transcriptase enzyme. This viral DNA gets incorporated into the host cell's DNA and directs the infected cells to produce viruses. The macrophages produce virus and act like a HIV factory. Simultaneously HIV virus enters into helper T lymphocytes where it replicates and produces other viruses. This is repeated so that the number of T lymphocytes decreases in the body of the infected person. During this period, the infected person suffers from fever, diarrhoea and weight loss. Since the number of helper T lymphocytes decreases in the body, the person starts suffering from infections of bacteria especially *Mycobacterium*, viruses, fungi and even parasites like *Toxoplasma*. The patient gets immune deficiency and he/she is unable to protect himself/herself against these infections.

Transmission. Virus of AIDS is transmitted via blood and semen. (i) Transfusion of infected blood or blood products. (ii) Use of contaminated needles and syringes to inject drugs or vaccines. (iii) Use of contaminated razors. (iv) Use of contaminated needles for boring pinnae. (v) Sexual intercourse with an infected partner without a condom. (vi) From infected mother to child through placenta. (vii) Artificial insemination. (viii) Organ transplant.

AIDS Cannot be acquired by the following : (i) Insect bites, (ii) Crowded transport, (iii) Shaking hands, (iv) Sharing towels, (v) Coughing and sneezing, (vi) Kissing and embracing, (vii) Sharing utilities and telephone, (viii) Swimming pools and toilets.

Incubation period. The incubation period of AIDS ranges between 6 months to 10 years.

Symptoms. The symptoms of HIV infection include fever, lethargy, pharyngitis, nausea, headache, rashes, etc.

Diagnosis. AIDS can be diagnosed by **ELISA** test and **Western Blotting** test. Western blotting test is employed for confirmation of ELISA positive cases.

Treatment. Although there is no cure for AIDS, use of certain drugs can prolong the life of AIDS patient. **Zidovudine** or **AZT** (azidothymidine) was the first drug used and continues to be the drug of choice for the treatment of AIDS. **Didanosine** (dideoxyionosine, **DDI**) is another drug employed to treat AIDS.

Prevention (Prophylaxis). No vaccine has been prepared so far against AIDS virus. The following steps may help in preventing AIDS.

(i) People should be educated about AIDS. Every year, **December 1** is recalled as the **World AIDS Day**. It is one of the methods to educate the people about AIDS.

(ii) Blood test must be done in blood donors, donors of semen, donors of organs (kidney, lung, liver), patients undergoing haemodialysis, and pregnant women.

(iii) Disposable needles and syringes should be used. Used needles and syringes must be destroyed.

(iv) In sexual relationship one should be monogamous.

(v) Dentists should use sterilized equipments.

(vi) Avoid tatoos, ear and nose piercing from unqualified people.

(vii) Avoid use of common blades in barber's shop.

Many people are ignorant about AIDS and it has been said that "don't die of ignorance". NACO (National AIDS Control Organization) and other NGOs (Non Governmental Organisations) are doing good work to educate people about AIDS.

AIDS- Related Complex (ARC)

It is mild form of AIDS. Its symptoms are swollen lymph nodes, fever, sweating at night and weight loss. Patients with ARC have a high possibility of early development of AIDS. ARC is also known as prodromal AIDS (symptoms before AIDS).

Differences between SCID (Severe Combined Immunodeficiency Disease) and AIDS	
SCID	AIDS
1. It is genetic disorder.	1. It is caused by Human Immunodeficiency Virus (HIV).
2. The individuals are born without T-cells and B-cells.	2. HIV attacks helper T cells and, therefore, helper T cells reduce in number.
3. This disorder is found in new born children.	3. Virus of AIDS can be transmitted at any stage.

Organ Transplantation and Immunosuppressants

Transplantation involves the removal of damaged/injured tissues or organs from the body of a person and their substitution by similar tissues/organs from a donor.

The world's first successful organ transplant was kidney transplantation which was undertaken by David Hume and Joseph Kelly at the Peter Brigham Hospital in Boston in 1954. The first kidney transplant in India was performed on Dec. 1, 1971 at the Christian Medical College, Vellore (Tamil Nadu).

Organs which are transplanted. Transplants of organs that are now feasible include bone marrow, lungs, heart, liver, cornea and also kidneys as written above.

- Alexis Carrel was awarded the Nobel Prize in 1912 for research in transplantation of tissues and organs. He is considered the "Father of Organ Transplantation".

Types of organ transplantation. Organ transplantation is of four types.

1. **Autograft.** It is grafting of one's own tissue to another part of the body, e.g., skin graft. It is most successful transplantation.

2. **Isograft.** It is transplantation from a twin brother or sister i.e., donor and recipient are genetically identical.

3. **Allograft.** It is the transplantation between individuals of same species, but with different genetic background.

4. **Xenograft.** It is transplantation between animals of different species.

Tissue matching, blood group matching are essential before undertaking any graft/transplant. Transplantation may result in the **rejection of transplanted organs**. The immune system recognizes the protein in the transplanted tissue or organs as foreign and initiates **cellular immunity**. To suppress the immune response during transplantation, histocompatibility antigen and immunosuppressants play an important role.

(i) **Histocompatibility** is the property of having the same or mostly the same alleles of a set of genes called the major histocompatibility complex. The **major histocompatibility complex (MHC)** is a set of molecules displayed on cell surfaces that are responsible for lymphocyte recognition and antigen presentation. It is encoded by several genes located on human **chromosome 6**. Major histocompatibility complex (MHC) is also referred as the **HLA** (or Human Leucocyte Antigen) **System** in humans.

(ii) **Immunosuppressive drugs or immunosuppressants** are drugs, that are used to prevent rejection. A kidney transplant from an identical twin, is always successful. If kidney is transplanted from other person except twin is also successful with the use of an **immunosuppressant**. The drug, named **cyclosporin** is a good immunosuppressant. Cyclosporin A is produced by *Trichoderma polysporum*. It destroys T-cell mediated immune responses, while spares humoral antibody responses. This drug prevents rejection of kidney, heart and liver transplants.

CANCER

What is Cancer ? Cancer is an abnormal and uncontrolled division of cells, known as cancer cells, that invade and destroy the surrounding tissues. Generally cancer is defined as uncontrolled proliferation of cells without any differentiation. Cancer cells are different from normal cells in some aspects. They do not remain confined to one part of the body. They penetrate and infiltrate into the adjoining tissues and dislocate their functions. Some of the cancer cells get detached from the main site of origin and travel by blood and lymph to sites distant from the original tumour and form fresh colonies, called metastasis or secondary growth.

Differences between Cancer Cells and Normal Cells	
Cancer Cells	Normal Cells
<ol style="list-style-type: none"> 1. These cells divide in an unregulated/uncontrolled manner. 2. Their life span is not definite. 3. These cells do not respond to control mechanisms and do not show contact inhibition. 	<ol style="list-style-type: none"> 1. These cells divide in a regulated manner. 2. They have a definite life span. 3. They live in a complex interdependent manner and show the phenomenon of contact inhibition.

How Cancer Cells Differ from Normal Cells ? Normal cells have a limited life span. They are usually replaced by new cells through cell division and cell differentiation. Their production is regulated in such a manner that the number of a given cell type remains nearly constant. Normal cells show a property called **contact inhibition**. Due to this property they contact with other cells, inhibit their uncontrolled growth. Cancer cells seem to have lost this property. But cancer cells do not respond to normal growth control mechanism. These cells proliferate in an unregulated manner and form clones of cells which can expand irregularly. This uncontrolled growth is called **tumour** or **neoplasm**.

Types of Tumours. There are two types of tumours: benign and malignant.

(i) **Benign Tumour (= Nonmalignant Tumour).** It remains confined to the site of its origin and does not spread to other parts of the body. It causes limited damage to the body. It is non-cancerous.

(ii) **Malignant Tumour (= Cancerous Tumour).** It first grows slowly. No symptoms are noticed. This stage is called the **latent stage**. The tumor later grows quickly. The cancer cells go beyond adjacent tissue and enter the blood and lymph. Once this happens, they migrate to many other sites in the body where the cancer cells continue to divide. A phenomenon in which cancer cells spread to distant sites through body fluids to develop secondary tumour is called **metastasis**. Only malignant tumours are properly designated as cancer.

Differences between Benign Tumour and Malignant Tumour

<i>Benign Tumour</i>	<i>Malignant tumour</i>
1. It remains confined to the affected organ.	1. It also spreads to other organs of the body.
2. Rate of growth is usually slow.	2. Rate of growth is usually rapid.
3. There is no latent stage.	3. There is latent stage.
4. There is no metastasis.	4. There is metastasis.
5. It is non-cancerous.	5. It is cancerous.

Properties of Cancer Cells. (i) Uncontrolled proliferative ability. (ii) Extracellular growth factors are not required. (iii) Overgrowth and ability to invade new sites (metastasis). (iv) Nucleus becomes irregular with abundant granules. (v) There is increase in number of lysosomes, reduction in mitochondrial cristae, more melanin and debris in cytoplasm. (vi) Cancer cells resist induction of cell death which promotes development of tumours.

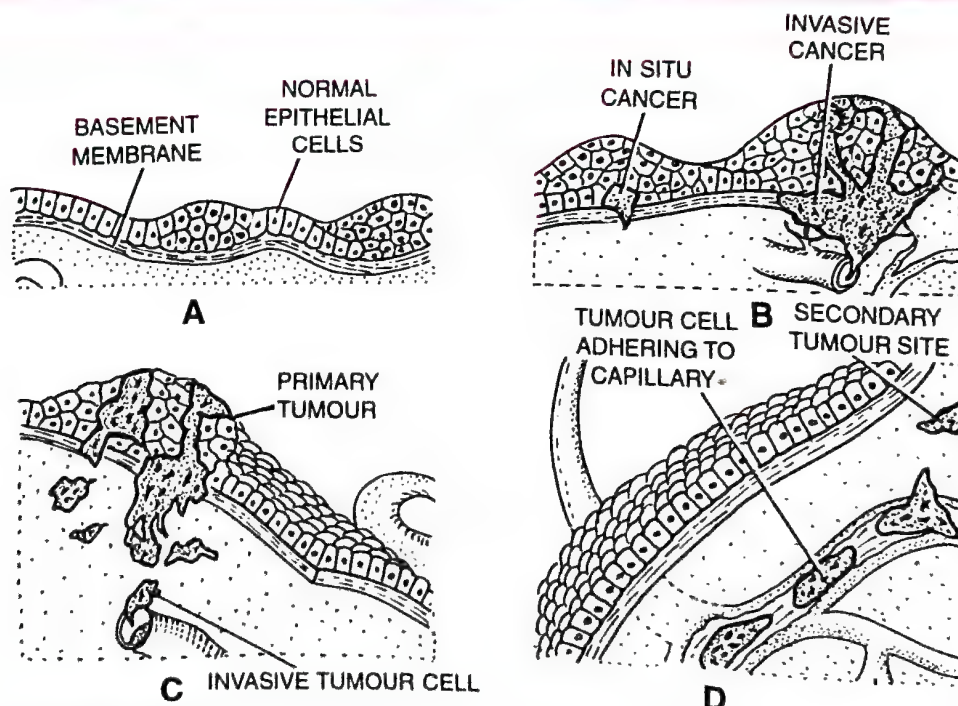


Fig. 8.21. Stages in development of cancer. Primary tumour may become metastatic and get transformed into secondary tumour.

Types of Cancers. Cancers are classified on the basis of the tissue from where they arose. Cancers are of three main types :

1. **Carcinomas.** This type is mainly derived from *epithelial cells*. They include cervical (cervix is part of uterus) cancer, breast cancer, skin cancer, brain cancer, lung cancer, stomach cancer, etc. About 80% of all tumours are carcinomas.

- (i) Cancerous growth of melanocytes (a type of skin cells) is called **melanomas**.
- (ii) Cancer of glands is called **adenocarcinoma**.

2. **Sarcomas.** These cancers are derived from *mesoderm*. They include the cancers of bones, cartilages, tendons, adipose tissue and lymphoid tissue.

- (i) Cancer of bones is called **osteoma**.
- (ii) Cancers of adipose tissue are known as **lipomas**.

(iii) Cancer of lymphoid tissues is called **lymphoma**. **Hodgkin's disease** is an example of human lymphoma. In Hodgkin's disease there is chronic enlargement of the production of lymphocytes by lymph nodes and spleen. They are rare in humans; about 1 per cent of all tumours are sarcomas.

3. **Leukemias.** Leukemias (= leukaemias) are characterised by abnormal increase of white blood corpuscles count due to their increased formation in the bone marrow. Leukemias are commonly called **blood cancers**.

- Cancer of muscle tissue is known as **myoma**.
- Cancer of glial cells of central nervous system is called **glioma**.
- World Cancer Day — Feb. 4

The most common cancers in India are mouth-throat cancer in men and uterine-cervical cancer in women.

Differences between Carcinoma and Sarcoma

<i>Carcinoma</i>	<i>Sarcoma</i>
1. It is the malignant growth of epithelial tissues that are ectodermal in origin. 2. Examples : Lung cancer and breast cancer.	1. It is the malignant growth of tissues derived from primitive mesoderm. 2. Examples : Bone cancer and cancer of lymph nodes.

Causes of Cancer. Study of cancer cells is called **oncology**. Chemical and physical agents that can cause cancer are called **carcinogens**, which belong to three categories.

(i) **Oncogenic Transformations.** They are agents or factors which bring about changes in genetic material. They are of two types, radiations and chemicals.

(ii) **Tumour Promoters.** They promote proliferation of cells which have undergone oncogenic transformation, e.g., some growth factors, hormones.

(iii) **Tumour Viruses.** Some viruses are known to be connected with oncogenic transformations.

Another classification of carcinogens is as follows :

1. **Physical irritants.** (i) Use of **Kangri** (an earthen pot containing burning coal) by Kashmiris causes abdominal skin cancer as these people keep Kangri close to their abdomen

during winter. (ii) **Betel and tobacco chewing** causes oral cancer. (iii) **Heavy smoking** causes lung cancer and may also cause cancer of oral cavity, pharynx (throat) and larynx. (iv) **Jagged teeth** may cause tongue cancer. (v) **Excessive exposure** to sun light can cause skin cancer.

2. **Chemical Agents.** Several chemicals are known to cause cancer. These are caffeine, nicotine, products of combustion of coal and oil and pesticides; constant use of artificial sweetener can cause cancer. An animal protein-rich diet is known to cause cancer of large intestine. Breast cancer has hormonal relationship. Thus, some sex hormones and steroids if secreted or given in large amounts may cause cancer. Chimney sweepers can develop cancer of scrotum. Dye workers have a high rate of bladder cancer.

Carcinogens and Organs Affected

<i>Carcinogens</i>	<i>Organs Affected</i>
1. Soot	Skin, lungs
2. Coaltar (3, 4-benzopirene)	Skin, lungs
3. Cigarette smoke (N-nitrosodimethylene)	Lungs
4. Cadmium Oxide	Prostate gland
5. Aflatoxin (a mould metabolise)	Liver
6. 2-naphthylamine and 4-aminobiphenyl	Urinary bladder
7. Mustard gas	Lungs
8. Nickel and Chromium compounds	Lungs
9. Asbestos	Lungs, pleural membrane
10. Diethylstilbesterol (DES)	Vagina
11. Vinyl chloride (VC)	Liver

3. **Radiations.** The X-rays, cosmic rays, ultra-violet rays, etc. can cause cancer. Japanese people exposed to radiations from World War II nuclear bombing show five times the incidence of leukemia seen in the rest of the population.

4. **Biological Agents.** Some viruses and other parasites, excessive secretion of certain hormones are believed to cause cancers.

Cancer and Genes. Cancer-associated genes are divided into the following three categories.

(i) Cancer causing viruses are called **oncogenic viruses**. The genes of oncogenic viruses are known as **viral oncogenes**. It is now held that all cells carry some cancer causing genes called **oncogenes** which when activated under certain conditions could change into **oncogenic cells**. **Jumping genes** are often involved in this conversion.

(ii) Tumour suppressor genes that inhibit cell proliferation.

(iii) Genes that regulate programmed cell growth.

How Cancer Spreads? Abnormal increase in number of cells in a tissue or organ forms a clone of proliferative cells. This excessive proliferation gives rise to a mass of cells which is initially known as benign tumour. The benign tumour cells enter into the blood vessels and migrate to other sites in the body where these cells continue to divide, such tumour cells are known as malignant cells and tumours are called malignant tumours. The malignant tumours are designated as cancer.

Detection and Diagnosis of Cancer. It depends upon histological features of malignant structure. (i) Bone marrow biopsy (a piece of the suspected tissue cut into thin sections is stained and examined under microscope by a pathologist) and abnormal count of WBCs in leukemia. (ii) Biopsy of tissue, direct or through endoscopy. Also endoscopic observation. **Pap's test** (cytological staining) is used for detecting cancer of cervix and other parts of genital tract. (iii) Techniques such as radiography (use of X-rays), **CT** (computed tomography), **MRI** (magnetic resonance imaging) are very useful to detect cancers of the internal organs. In CT, X-rays are used to generate a three dimensional image of internal organs. In MRI strong magnetic fields and non-ionizing radiations are used to detect pathological and physiological changes in the living tissue. Antibodies against cancer specific antigens are also used for detection of certain cancers. Techniques of molecular biology can be applied to detect genes in individuals. **Mammography** is radiographic examination of breasts for possible cancer. (iv) **Monoclonal antibodies** coupled to appropriate radioisotopes can detect cancer-specific antigens and hence cancer. (v) **Ames Test** is for carcinogenic disease.

Different Sites of Cancer. Some of the important sites of cancer are skin, mouth, oesophagus, stomach, colon, rectum, liver, gall bladder, pancreas, blood, lymph, adipose tissue, lung, uterine cervix, breast, brain, penis, prostate, muscles, thyroid, kidney and bones.

Possible Symptoms of Cancer. (i) A persistent cough or hoarseness in a smoker. (ii) A persistent change in digestive and bowel habits. (iii) A change in a wart or mole. (iv) A lump or hard area in the breast. (v) Unexpected diminished or lost appetite. (vi) Unexplained low-grade fever. (vii) Unexplained loss of weight. (viii) Any uncurable ulcer. (ix) Bleeding in vagina at times other than the menstruation. (x) Non-injury bleeding from the surface of the skin, mouth or any other opening of the body.

Treatment of Cancer. Four general methods of treatment for cancer are currently available.

1. **Surgery.** It involves the removal of the entire cancerous tissue.

2. **Radiotherapy.** It involves the exposure of the cancerous parts of the body to X-rays which destroy rapidly growing cells without harming the surrounding tissue. Radon (Rn-220), Cobalt (Co-60) and Iodine (I-131) are radioisotopes which are generally used in radiotherapy.

3. **Chemotherapy.** It involves the administration of certain anticancer drugs. These drugs check cell division by inhabiting DNA synthesis. These drugs may be more toxic to cancerous cells than to normal cells. Thus chemotherapeutic drugs kill cancerous cells. Majority of drugs have side effects like hair loss, anaemia etc. A common weed *Catharanthus roseus* is the source of two anticancer drugs, **Vincristine** and **Vinblastine** used in the treatment of leukaemia.

4. **Immunotherapy.** It involves natural anti-cancer immunological defence mechanisms. The patients are given substances called *biological response modifiers* such as α -interferon which activate their immune system and help in destroying the tumour.

Most cancers are treated by combination of surgery, radiotherapy and chemotherapy.

Efforts are being made to develop cancer vaccines.

Harald Zur Hausen shared 2008 Nobel Prize for Physiology or Medicine for finding human papilloma viruses (HPV) that cause cervical cancer, the second most common cancer in women around world.

Catharanthus roseus plant is the source of anticancer drugs.

Taxol drug is anticancer drug for breast and ovarian cancer. It is obtained from pacific yew (*Taxus buccata*)

ADDICTION

Addiction is the habitual, physiological and psychological dependence on a substance or practice which is beyond voluntary control. A person who is habituated to a substance or a practice, especially a harmful one, is called an **addict**. Addiction is a chronic, progressive and sometimes fatal disorder with both genetic and environmental roots. It manifests as a compulsion that drives an individual to continue to behave in a way that is harmful to self and loved ones, despite an intense desire to halt that behaviour. It is a disease of "more" – an active addict needs an increasing amount of substance to get high and is unable to cease usage without painful withdrawal symptoms. This is true whether the addictive substance is a drug or tobacco or alcohol or a behaviour, such as gambling or sexual promiscuity. Medically, addiction is of three types: Tobacco Addiction, Alcohol Addiction, Drug Addiction,

Tobacco Addiction/Tobacco Abuse

Source of Tobacco. Tobacco (*Nicotiana tabacum* and *Nicotiana rustica*) belongs to the family *Solanaceae*. It is a native of South America, where the Red Indians first started smoking dried and cured leaves of its young form.

Modes of Tobacco Use. Tobacco is used for smoking, chewing and snuffing. (i) Inhaling tobacco smoke from cigars, cigarettes, bidis, pipes and hubble-bubble (called HUKKA in Northern India) is called smoking. (ii) Tobacco in powder form is chewed with Paan. It is also placed between the lip and the gum for a period of time and then spat out. (iii) When powdered tobacco is taken through nose it is called **snuffing**.

Development of Tobacco Addiction. Persons start smoking/chewing tobacco due to imitation of elders, show off, fun and curiosity, defiance to elders, relaxation, working long hours, peer group or group pressure, adventure, sense of freedom and advertisements and scenes in movies.

Ingredients of Tobacco Smoke

Substance	Effect (s)
Particulate Ingredients	
"Tar"	Carcinogen
Polynuclear aromatic hydrocarbons	
Nicotine	Neuroendocrine stimulant and depressant; addicting drug
Phenol	Cocarcinogen and irritant
Cresol	
β -Naphthylamine	Carcinogen
N-Nitrosornicotine	
Benzo[a]pyrene	

Trace metals (e.g., nickel, arsenic, polonium 210)	Carcinogens
Indole	Tumor accelerator
Carbazole	
Catechol	Cocarcinogen
Gaseous Ingredients	
Carbon monoxide	Impairs oxygen transport & utilization
Hydrocyanic acid	Ciliotoxin and irritant
Acetaldehyde	
Acrolein	
Ammonia	
Formaldehyde	
Oxides of nitrogen	Carcinogen
Nitrosamines	
Hydrazine	
Vinyl chloride	

- **Tar.** It is thick viscid dark coloured liquid which gets deposited over the internal surface of **respiratory tract**. Tar is also carcinogenic or cancer causing.
- **Ciliotoxins.** They are harmful to cilia present over the lining cells of nasal tract. Cilia are important in pushing out particles from the nasal tract. Ciliotoxins kill cilia and, therefore, prevent cleaning of respiratory passage.

Effect of Nicotine. Smoking was reported to produce a feeling of tranquility (calmness) and in some cases made people alert and active. **Nicotine** is the major stimulatory component of tobacco products including cigarettes. It is highly *poisonous* as well as a *habit forming alkaloid*. It stimulates the release of **adrenaline** leading to high blood pressure and heart beat rate. The increased blood pressure caused by smoking leads to increased risk of heart disease. In pregnant women nicotine causes retardation and abnormal growth of the foetus. In males, it produces **infertility**.

Effects of Carbon Monoxide. *Carbon monoxide* is a toxic gas that interferes with oxygen transport and utilization. Because cigarette smoke contains 2 to 6 percent carbon monoxide, smokers inhale concentrations as high as 400 parts per million (ppm) and develop elevated carboxyhemoglobin (COHb) levels. The range of COHb found in smokers is 2 to 15 percent, while levels for nonsmokers are near 1 percent. The average COHb level of moderate cigarette smokers is 5 percent. Carbon monoxide produces its adverse effects by reducing the amount of available oxyhemoglobin and myoglobin and by displacing the oxygen-hemoglobin dissociation curve to the left. Chronic, mild elevations of COHb due to smoking are a common cause of mild polycythemia and may produce subtle impairment of central nervous system function.

Diseases Caused by Smoking. Following diseases are caused by smoking.

1. **Cancer.** Benzpyrene present in tobacco smoke causes lung and throat cancer.
2. **Cardiovascular Diseases.** Cigarette smoking, hypertension and hypercholesterolemia are the three major CHD (coronary heart disease) risk factors for cardiovascular diseases.

3. **Smoker's Cough and Bronchitis.** Tobacco smoke irritates the mucous membrane of the throat and bronchi causing cough and bronchitis.

4. **Emphysema.** Tobacco smoke may breakdown the lung alveoli which reduces the surface for gas exchange.

5. **Pulmonary Tuberculosis.** Smoking hubble-bubble can spread bacteria of pulmonary tuberculosis from infected to healthy persons.

6. **Passive Smoking.** Involuntary or passive smoking causes an irritant effect such as ocular (eye) burning. It can cause lung cancer and may also cause coronary heart disease.

Withdrawal Symptoms and Deaddiction

Withdrawal Symptoms include anxiety, nervousness, irritability, depression, insomnia, dryness of throat, disturbed bowels, lack of concentration, increased appetite and craving for tobacco.

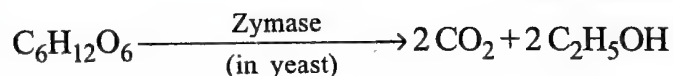
Deaddiction requires **psychotherapy** when the patient is informed of harmful effects on self and family members. The patient is also told about the withdrawal symptoms. If the addict is unable to stop the use of tobacco, deaddiction is achieved under supervision of experts through **replacement therapy**.

- **Central Tobacco Research Institute** is situated at **Rajahmundry (A.P.)**.
- **World Anti-tobacco Day** is celebrated on May 31.

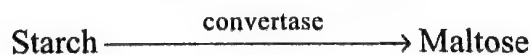
Prevention. Primary smoking prevention in adolescent age group may be the most effective programme. Young people who have been trained to resist social pressures, who understand the health consequences of smoking and who appreciate the difficulty of quitting are less likely to start smoking.

ALCOHOL ADDICTION/ABUSE

Source of Alcohol. The word **alcohol** refers to **ethyl alcohol** or **ethanol** (C_2H_5OH). Alcohol is manufactured by fermentation of sugars.



Industrial alcohol is obtained by fermentation of starchy grains by the yeast—*Saccharomyces cerevisiae*. Fermentation proceeds till alcohol content reaches 15 %. After this, the reaction is inhibited by alcohol itself. Starchy cereals like barley, when soaked produce malt.



Maltose can be fermented by yeast to produce alcohol. The major source of commercial alcohol is *molasses*, a byproduct of sugar industry.

Alcohol Abuse. When drinking of excessive alcohol is done that impairs one's physical, physiological and psychological function. It constitutes **alcohol abuse**.

The dependence or addiction of alcohol is called **alcoholism** and the addict is termed as **alcoholic**. WHO declared in 1964 that alcoholism is a disease.

Absorption of Alcohol (=Ethanol). Alcohol is absorbed from mucous and oesophagus (in very small amounts) and from the stomach, from the proximal portion of the small

intestine (the major site) and large intestine (in modest amounts). The rate of alcohol absorption from stomach is dependent on its concentration, presence of food and other factors.

Some of the commonly used beverages, their source and alcohol content are tabulated below.

Beverage	Source	Alcohol Content per cent
1. Beer	Barley grains	3 – 6
2. Sherry	Grape juice	16 – 22
3. Champagne	Grape juice	12 – 16
Wine. Fermented juice of any fruit, usually made from grapes and containing 10% to 15% alcohol.		
4. Rum	Mollases	40 – 55 %
5. Gin	Barley	– do –
6. Whisky	Barley	– do –
7. Brandy	Fruits of Peaches, Apples and Cherries	60 – 70 %
8. Vodka— much used in Russia	Cereals,	40 – 55 %
9. Sake in Japan	Rice	– do –

What happens when Alcohol is taken ? Alcohol is quickly absorbed in the stomach and upper part of small intestine and is transferred to the blood. This blood carries alcohol to the liver where liver synthesises fat from alcohol. The liver is an important centre of carbohydrate, fat and protein metabolism. The excess of fat reduces the formation of glycogen and structural proteins. But due to excess of fat the liver becomes store house of fat. From the liver alcohol follows the following route through blood → heart → lungs → heart → various body parts where oxidation starts so that some amount of energy is produced which gives false impression of warmth in the body.

Is Alcohol a Stimulant ? Many people think that alcohol is a stimulant. But alcohol is not a stimulant. Actually alcohol acts as sedative (lessens functional activity), analgesic (relieves pain) and anaesthetic (causes loss of sensation).

Problems caused by Alcohol. Three types of problems are caused by alcohol drinking.

(i) **Social problems.** These include absence from work, unemployment, marital (marriage) tensions, child abuse, financial difficulties and problems with law, including violence and traffic offences.

(ii) **Psychological problems.** Heavy drinking causes depression. Suicide attempt is much commoner in alcoholics than in the rest of society. Sexual relationship is usually deteriorated because of impotence or rejection by the partner.

(iii) **Physical Problems.** These are variable and can affect virtually any organ in the body.

Effects of Alcohol Abuse

It has been proved that the intake of alcohol affects individual health, family life and ultimately creates several community and social problems.

1. **Deficiency of Nutrients.** Deficiency of nutrients such as minerals, proteins and vitamins are found in alcoholics. Low blood potassium, magnesium, calcium, zinc and phosphorus can occur in alcoholics. Vitamins like thiamine (B_1), nicotinic acid (B_3), pyridoxine (B_6), folic acid,

ascorbic acid (vitamin C) and vitamin A may be deficient in alcoholics. *Thiamine* (B_1) deficiency causes **Wernicke's and Korsakoff's syndrome**. Wernicke's syndrome (= Wernicke's disease or encephalopathy) is characterized by mental disturbance, paralysis of eye movements and **ataxia** (a loss of the power of muscular co-ordination) of **gait** (manner of or carriage in walking). Korsakoff's syndrome (= Korsakoff's psychosis) is characterised by confusion and severe impairment of memory, especially for recent events.

2. **Effects on immunity.** Chronic alcoholics neglect their health and soon the body loses its resistance against infections.

3. **Effect on the Brain.** *Alcohol is depressant to the brain.* Even after only a few drinks, alcohol decreases sleep and depresses rapid eye movement (REM). The overall effect is likely to be repeated awakenings and a sense of restless sleep.

In alcoholism, cerebrum is affected first (person loses judgement, self control and will power) followed by cerebellum (coordination of muscles is lost). This results in double and blurred vision, slurring of speech, loss of consciousness and inability to judge distances.

4. **Effect on Cardio Vascular System (CVS).** (i) *Small doses* dilate the blood vessels of skin (specially of the face) and stomach. Blood pressure is not affected.

(ii) *Moderate doses* cause tachycardia (increase heart beat), and mild rise in blood pressure.

(iii) *Large doses* cause direct myocardial and vasomotor centre depression and there is fall in blood pressure.

Chronic alcoholism may lead to cardiomyopathy, the disease of myocardium.

Regular intake of **small to moderate amounts** has been found to *raise HDL* – high density lipoproteins (good cholesterol) and lower *LDL* – low density lipoproteins (bad cholesterol) levels in the blood plasma. Alcohol also reduces blood sugar level which is harmful to the functioning of brain.

5. **Mallory Weiss Syndrome.** Dilute alcohol (optimum 10%) stimulates gastric secretion (specially acid). Acute alcoholic intake can result in inflammation of the oesophagus (**oesophagitis**) and stomach (**gastritis**). Chronic heavy drinking, if associated with violent vomiting, can produce a longitudinal tear in the mucosa at the gastrointestinal junction – a **Mallory- Weiss Syndrome** (also called Mallory – Weiss lesion).

6. **Diseases of Liver.** Absorbed alcohol is carried directly to the liver, where it becomes the preferred fuel. Use of moderate amounts of alcohol does not cause liver damage, provided adequate nutrition is maintained. However, chronic alcoholism causes the following diseases.

(i) **Alcoholic fatty liver.** The liver becomes enlarged, yellow, greasy and firm. It increases the fat synthesis in the liver. It leads to fatty liver syndrome.

(ii) **Alcoholic hepatitis.** It is characterised by degeneration of hepatocytes. The damaged (degenerated) hepatocytes are surrounded by polymorphonuclear leucocytes. These hepatocytes may be pale and swollen and some contain dense eosinophilic masses called **Mallory's hyaline**. Alcoholic hepatitis is often a precursor of cirrhosis.

(iii) **Alcoholic cirrhosis.** With continued alcohol intake, there is destruction of hepatocytes and fibroblasts (cells which form fibres) and stimulation of collagen protein formation. Due to continuing hepatocyte destruction and collagen deposition, the liver shrinks in size, acquires a nodular appearance and becomes hard leading to cirrhosis.

(iv) **Cholestasis.** It is a stoppage in the flow of bile. It is characterised by jaundice, abdominal pain and hepatomegaly (enlargement of liver).

7. **Pancreatitis.** Heavy drinking of alcohol can cause acute and chronic pancreatitis.
8. **Increased cancer risk.** Alcoholics have a rate of carcinoma 10 times higher than that expected in the general population. Acute and chronic alcoholism can cause oropharyngeal, oesophageal, stomach, liver, pancreas and according to recent data, breast cancer.
9. **Effect on Kidneys.** Diuresis (increased urine output) is often noticed after alcohol intake. This is due to water intake with drinks and alcohol induced inhibition of ADH (Antidiuretic Hormone) secretion. Deficiency of ADH causes more urine output.
10. **Effect on Respiratory Centre.** The direct action of alcohol on respiratory centre in the brain is only depressant one.
11. **Effect on Haemopoietic System.** Alcohol increases RBC size causing a mild anaemia. Chronic heavy drinking can also decrease production of white blood cells (WBCs). Alcohol may decrease platelet aggregation.
12. **Alcoholic Myopathy.** Heavy drinking can cause an acute **alcoholic myopathy** characterized by painful and swollen muscles and high levels of serum creatine phosphokinase (CK).
13. **Impotency and Infertility.** Chronic alcoholic men may show testicular atrophy with shrinkage of the seminiferous tubules and loss of sperm cells. Thus chronic alcoholism can produce impotence and infertility. The repeated intake of high doses of alcohol by women can result in amenorrhea (loss of normal menstruation), a decrease in ovarian size, an absence of corpora lutea (sing. corpus luteum) with associated infertility and spontaneous abortions. Alcohol delays maturity in adolescents.
14. **Foetal Alcohol Syndrome (FAS).** Heavy drinking during pregnancy results in the **foetal alcohol syndrome (FAS)** which includes facial changes, poorly formed concha (cavity of pinna), small teeth with faulty enamel, defects in atria and ventricles of heart, limitation in joint movement and mental retardation.

Why Driving and Drinking do not go Together ?

It is due to the following facts : (1) **Alcohol affects judgement.** A person's ability to judge distance is distorted. (2) **Alcohol affects coordination.** Coordination of the limbs, the head and the eyes are impaired affecting the driver's control of the car. (3) **Alcohol affects vision.** Vision becomes blurred and unsteady. Often the field of vision is reduced and affects the power of accommodation (tunnel vision). (4) **Alcohol increases reaction time between sight and reaction.** The driver takes more time to react to unexpected situations, e.g., a child running across a street. Due to this, chances of accidents become high.

De-Alcoholism

Treatment of alcoholism is called de-alcoholism. It includes the treatment of withdrawal symptoms and the treatment of alcoholics. It requires help from family, friends and society to break off the habit.

1. **Treatment of Withdrawal Symptoms.** The first step is to perform a thorough physical examination in all alcoholics who are considering to stop drinking.

The second step is to give patients adequate nutrition and rest.

The third step is treatment. Thus Benzodiazepines are the *drugs of choice for withdrawal symptoms*.

The most effective treatment of severe withdrawal is controversial. Phenothiazines

(e.g., Chlorpromazine) — a group of antipsychotic drugs are required for alcohol hallucinosis. Other antipsychotic drugs such as Thioridazine or Haloperidol are sometimes used for delirium tremens (DTs). Delirium is a condition of extreme mental and usually motor, excitement, marked by a rapid succession of confused and unconnected ideas.

2. Treatment of Alcoholics. Motivation towards abstinence includes educating the patient about alcoholism and teaching the family members and friends to stop protecting the alcoholic from the problems caused by alcohol. The second is to *help the patient to readjust to life without alcohol* and to re-establish a functional lifestyle through personal counselling, vocational rehabilitation, family support.

They should follow a rigid bed time and awakening schedule and should avoid use of caffeine i.e., tea, coffee and cold drinks in the evening.

One medicine, **Disulfiram** has been used in alcohol rehabilitation. Disulfiram must not be given to patients with hypertension, diabetes mellitus, heart disease or a history of stroke because in such persons this medicine may be dangerous.

Alcoholics Anonymous (AA) is a self-help group of recovering alcoholics (men and women who have stopped drinking, perhaps many years ago). AA offers an effective model showing that abstinence can be achieved. The alcoholics should join Alcoholics Anonymous.

DRUG ADDICTION / DRUG ABUSE

It has been observed that use of drugs has been increased especially among youth. This is a matter of concern as it could cause many harmful effects. Proper education and guidance could safeguard themselves against these dangerous practices and lead a healthy life style.

Drug (French : **Drogue**— a dry herb) is the single active chemical entity present in a medicine that is used for diagnosis, prevention, treatment/cure of a disease. This disease oriented definition of drug does not include contraceptives or use of drugs for improvement of health. WHO (1966) has given a more comprehensive definition— "*Drug is any substance or product that is used or is intended to be used to modify or explore physiological systems or pathological states for the benefit of the recipient.*"

Drugs are normally used as medicines to help patients cope with mental illness like depression, insomnia and so on. But when drugs are taken for a purpose other than their normal clinical use in an amount, concentration or frequency that impairs one's physical, physiological and psychological functions, it constitutes **drug abuse**. The term "abuse" with respect to drug means (i) non-medical use (ii) non-prescribed use and (iii) use for having pleasure. A person, who takes a drug for a non-medical use is called **drug abuser** and drugs are called **habituating drugs** or **addictive drugs**.

Types of Habituating Drugs

The habituating drugs are of two main types : psychotropic drugs and psychodelic drugs.

A. Psychotropic (Gk. *psyche* – mind, soul; *trope* = a turning) Drugs

These are **mood alternating drugs** which affect behaviour and mental activity of a person. Psychotropic drugs are classified into four major groups : tranquillizers, sedative and hypnotics, opiate narcotics and stimulants.

1. **Tranquillizers.** They decrease tension and anxiety and produce a feeling of calmness without sedating and inducing sleep. Tranquillizers are of two types.

(i) **Phenothiazines (Major Tranquillizers).** These are antipsychotic drugs which have good effect in all types of psychosis, specially schizophrenia. In a psychotic patient, these drugs reduce aggressiveness. Thought and behaviour are gradually normalised and anxiety is relieved. Examples are Chlorpromazine and Reserpine, etc.

(ii) **Benzodiazepines (Minor Tranquillizers).** These drugs are used for anxiety and phobic conditions. Benzodiazepine is parent compound for the synthesis of many antianxiety drugs such as Diazepam (e.g., Valium, Calmpose), Flurazepam, Temazepam, Triazolam and Midazolam, Oxazepam and Alprazolam Clonazepam etc. Benzodiazepines (BZDs) are main antianxiety drugs. BZDs hasten sleep, reduce intermittent awakening and increase total sleep time. They produce skeletal muscle relaxation without disturbing voluntary activity.

2. **Sedative and Hypnotics.** **Sedative** is a drug that *reduces excitement*, assuage pain and lowers the physiological or functional activity leading to drowsiness or sleep. **Hypnotic** is also a drug that *induces sleep*. Sedative and hypnotics are more or less general CNS depressants. Sedative and hypnotics include *Barbiturates* and *Benzodiazepines*.

(i) **Barbiturates.** These are *synthetic* drugs which are derivatives of barbituric acid. Barbiturates are **general depressants** for all excitable cells but the CNS is most sensitive to these drugs. These are taken to reduce anxiety and induce sleep. They are popularly called **sleeping pills**. Continuous use of the drug results in permanent damage to brain. Sudden withdrawal causes epilepsy. Examples : Phenobarbitone and Mephobarbitone. Barbiturates when taken alongwith alcohol, cause dramatically increased depressant effect. Barbiturates are not preferred these days.

(ii) **Benzodiazepines (BZDs).** These are antianxiety as well as sedative drugs and have been described earlier.

3. **Opiate/Opioid Narcotics.** The drugs derived from opium alongwith their synthetic relatives are called *opiates* or *opioids*. The drug that relieves pain by acting on the CNS is termed as **analgesic (pain killer)**. Opioids bind to specific opioid receptors present in our central nervous system and gastrointestinal tract. They are also called **pain killers**.

Opium (Afeem) is latex from unripe fruits (capsules) of poppy plant, *Papaver somniferum* (family Papaveraceae). It is reddish-brown in colour. It has heavy smell and bitter taste. It is eaten or smoked. Opiates have narcotic, analgesic, astringent (that causes contraction of body parts), and sedative effect. They slow down respiratory activity, cause constriction of pupil of eye, decrease glandular secretions, impair the digestion, produce nausea, vomiting and sterility. The opium addict loses weight, fertility and interest in work.

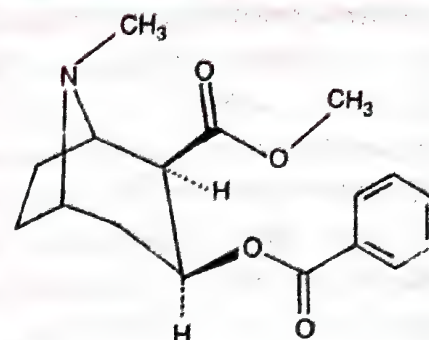
Opium Derivatives. Opium contains about 20 alkaloids. Main derivatives of opium are morphine and codeine.

(i) **Morphine.** It is the active principal alkaloid of opium. Its chemical formula is $C_{17}H_{19}NO_3$. It was isolated by Serturmer in 1805 and named it 'morphine' after the Greek



Papaver Somniferum
(Opium poppy).

god of dreams *Morpheus*. It is the principal opium alkaloid. It is a *strong analgesic*. It also has sedative and calming effect. The person lacks initiative and is unable to concentrate. Morphine depresses respiratory centre. It contributes to the fall in BP. It can cause bradycardia (slow heart beat). Morphine can release ADH and reduce urine output. *Constipation is a prominent feature of morphine action*. Morphine causes mild hyperglycaemia. It causes addiction. Diacetylmorphine hydrochloride is brown sugar/smack and is more powerful analgesic than morphine. Morphine is a very effective sedative and painkiller. It is very useful in patients who have undergone surgery. However, its continued use causes dependence.



Chemical Structure of Morphine.

Types of Opiate/Opioid Narcotics*

Natural opiates
e.g., Morphine, Codeine

Semisynthetic opiates
e.g., Heroin, Smack

Synthetic opiates
e.g., Pethidine, Methadone

(ii) **Codeine**. It is also a derivative of opium. Infact it is *methyl-morphine* which occurs naturally in opium and is partly converted in the body to morphine. It is *mild analgesic*. It does not cause addiction. It is an ingredient of many medicines and cough syrups. *Its prominent side effect is constipation*.

(iii) **Heroin** (*Diamorphine or Diacetylmorphine*). It is about 3 times more potent than morphine. Because of its high potency, it has been favoured in illicit drug trafficking. Hence it has been banned in most countries. Its chemical formula is $C_{17}H_{17}(OC_2H_3O)_2ON$. *Heroin is formed from morphine by acetylation*. It is highly addictive and, therefore, considered *most dangerous opiate*. Heroin is taken orally, or inhaled or injected. Heroin is a *depressant* and slows down body functions. Pure drug is seldom taken. It induces drowsiness and lethargy. Its after effects include indigestion, reduced vision, decreased weight, sterility and total loss of interest in work. As the heroin addicts are careless about syringes and needles for injection so this may cause blood poisoning, abscess formation, hepatitis-B and AIDS. Withdrawal symptoms of heroin include diarrhoea, vomiting, shivering, epilepsy.

(iv) **Smack**. It is a crude by-product of heroin synthesis and is commonly called "**brown sugar**". Being cheap, it is considered "poor man's heroin". A smack is stronger analgesic than morphine.

(v) **Pethidine (Meperidine)**. Although it is chemically unrelated to morphine yet it has many similar actions. Its analgesic efficiency is near to morphine and is more than codeine. It is equally sedative and euphoriant. It causes less histamine release and is safer in asthmatics. It has local anaesthetic action. It is mostly metabolized in liver.

(vi) **Methadone**. Its action is slightly stronger and longer than that of morphine to morphine. It has analgesic, respiratory depressant, constipating actions similar to morphine. Withdrawal symptoms are mild.

4. **Stimulants**. These drugs stimulate the nervous system; make a person more wake-

*Narcotics depress the activities of central nervous system. They also produce sleep.

ful, alert and active; and cause excitement. However, addiction is psychological and withdrawal of stimulant is followed by depression, anxiety and restlessness. The principal stimulants are as follows.

(i) **Caffeine.** Chemically, caffeine is **1,3,7 Trimethylxanthine**. Its chemical formula is $C_8H_{10}N_4O_2$. It is a white crystalline bitter alkaloid obtained from the leaves of tea plant, *Thea sinensis* of family Theaceae a shrub, seeds of coffee plant, *Coffea arabica* of family Rubiaceae, a shrub, seeds of cocoa plant, *Theobroma cacao* of family Sterculiaceae a tree yielding cocoa and chocolate. It is a mild stimulant and taken as beverages—tea, coffee, beats boredom, thinking becomes clear, improves performance. It acts as cardiac and respiratory stimulant. It is a mild diuretic (increases urine output). Caffeine increases contractile power of skeletal muscles. It increases BMR (Basal Metabolic Rate). It inhibits the release of histamine. Higher doses of caffeine cause nervousness, restlessness, panic, insomnia (lack of sleep) and excitement. Excessive intake of caffeine also causes addiction and indigestion and disturbs renal functions.

Classification of Stimulants

Natural Stimulants

1. Caffeine
2. Cocaine
3. Crack
4. Betelnut

Synthetic Stimulant Amphetamines

DRUGS YIELDING PLANTS

Common Name	Botanical Name	Family	Parts of the plant from which the product is obtained	Product Obtained
1. Poppy plant (=Opium poppy)	<i>Papaver somniferum</i>	Papaveraceae	Unripe fruits (capsules)	Opium (Afeem) and its derivatives— (e.g., morphine, codeine, heroin; pethidine and methadone)
2. Hemp plant	<i>Cannabis sativa</i> (<i>C. indica</i>)	Moraceae	Leaves and flowering tops	(i) Bhang, (ii) Ganja (iii) Charas/Hashish (iv) Marijuana
3. Coca plant (= Cocaine plant)	<i>Erythroxylon coca</i>	Erythroxylaceae	Leaves and Young twigs	Cocaine
4. Spineless Cactus (= Peyote Cactus)	<i>Lophophora williamsii</i>	Cactaceae	Dried tops (called mescals)	Mescaline (= Mescaline)
5. Tea plant (a shrub)	<i>Thea sinensis</i> *	Theaceae	Dried leaves	Tea
6. Coffee plant	<i>Coffea arabica</i>	Rubiaceae	Dried seeds	Coffee
7. Cocoa plant (=Sacred mushroom) (Small tree)	<i>Theobroma cacao</i>	Sterculiaceae	Dried seeds	Cocoa
8. Ergot fungus	<i>Claviceps purpurea</i>	Ascomycetes	Fruiting Bodies	LSD
9. Mexican mushroom	<i>Psilocybe mexicana</i>	Agaricaceae	Fruiting bodies	Psilocybine

Contain Caffeine

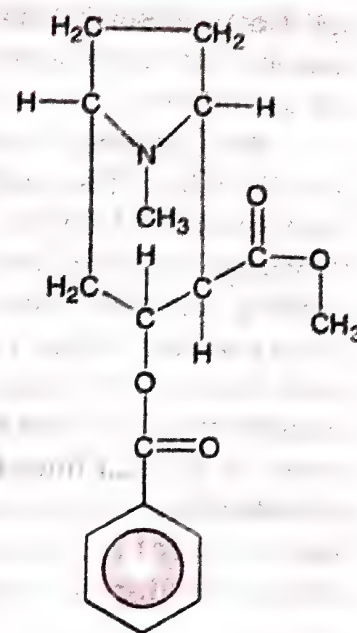
*Also called *Thea chinensis*.

(ii) **Cocaine.** It is natural **coca alkaloid** obtained from leaves of coca (= cocca) plant—*Erythroxylon coca* (family Erythroxylaceae)—a South American plant growing on the foot hills of Andes. Its chemical formula is $C_{17}H_{21}NO_4$. Cocaine is commonly called *coke* or *crack*. It is bitter, white, crystalline powder and called *snow*, *sniff*, *crack*, *coke*, *princess*, *Big C*. Cocaine has vasoconstrictor properties and therefore, is a good local anaesthetic. It is taken by snorting. It is a powerful CNS stimulant. It induces a sense of wellbeing and pleasure and **delays fatigue**. It increases heart beat, blood pressure and body temperature. It is smoked or injected or inhaled by addicts. It causes lack of sleep and loss of appetite. Its overdoses cause headache, convulsions, insomnia, respiratory or cardiac failure and may lead to mental disorder. Excessive dosage of cocaine causes hallucinations.

(iii) **Crack.** It is a derivative of cocaine. When it is smoked, it produces results within 10 seconds. Crack is relatively cheap but extremely addictive. It can cause heart and mental problems.

(iv) **Betelnut.** It is a mild CNS stimulant. It stains teeth and gum red. Kernel of the betelnut palm *Areca catechu*, enclosed in betal leaves and mixed with an aromatic paste is chewed in Africa and India. It contains an alkaloid arecoline ($C_8H_{13}NO_2$) and a red tannin.

(v) **Amphetamines.** They are synthetic drugs. They are commonly called **pep pills**, **anti sleep drugs** or **supermen** as they are CNS stimulants. Its chemical formula is $C_6H_5CH_2CH(NH_2)CH_3$. They cause alertness, self-confidence, talkativeness and increased work capacity. They stimulate respiratory centre. They cause wakefulness and postponement of sleep and hence called *antisleep drugs*. Since metabolism of amphetamines is slow, the drug is found in the urine for several subsequent days. Amphetamine is one of the drugs included in the 'dope test' for athletes. They do not remove fatigue. They suppress hunger (anorexia) and cause addiction. High doses of amphetamines produce euphoria, marked excitement, sleeplessness which may progress mental confusion. After effects include nausea and vomiting.



COCAINE ($C_{17}H_{21}O_4N$)

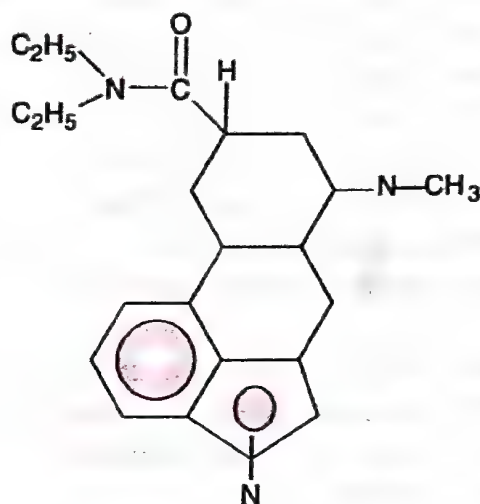
B. Psychedelic Drugs (= Hallucinogens)

These drugs change one's behaviour, thoughts, feelings and perceptions without any actual sensory stimulus. The hallucinogens, in general produce a dream-like state with the disorientation and loss of contact with reality without any true sensory stimulus. They cause hallucinations and often make users of SEE SOUND AND HEAR COLOUR. These are also called VISION PRODUCING DRUGS as they produce false imaginations or extreme feeling of either despair or euphoria by effecting cerebrum and sense organs. These include chemicals such as LSD (Lysergic acid diethylamide), Mescaline, Psilocybin and products of hemp plant. Cocaine and amphetamines are also capable of producing hallucinations.

Natural Hallucinogens

(i) **LSD (Lysergic acid diethylamide).** It is the *most powerful psychedelic* (= hallucinogen). Its chemical formula is $C_{15}H_{15}N_2CON(C_2H_5)_2$. It is a crystalline amidated alkaloid obtained from **ergot**, an extract got from fruiting body of fungus *Claviceps purpurea* that is parasite on Rye plant. It is always *smoked*. LSD was synthesized by Hofmann (1938).

LSD causes horrible dreams, emotional outbursts, hallucination, chronic psychosis and severe damage to the central nervous system. It also brings about chromosomal and foetal abnormalities. An LSD addict can be easily recognised from incoherence in writing and drawing.



L.S.D. (Lysergic acid diethylamide)

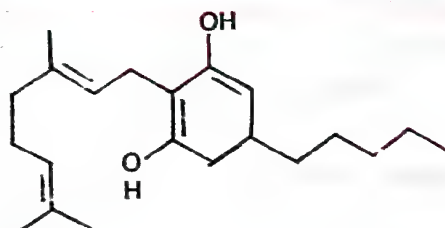


A bloom of rye showing grains infested with fungus (the black ones).

(ii) **Mescaline.** It is a white powdery alkaloid, obtained from the tops (called mescals) of a small spineless cactus, *Lophophora williamsii*, native to the SW United States and Northern Mexico. This cactus is also called "Peyote cactus". Its chemical formula is $C_{11}H_{17}NO_3$. It is a low potency hallucinogen.

(iii) **Psilocybine.** It is obtained from the fruiting bodies of Mexican mushroom (fungus) *Psilocybe mexicana*. (Family Agaricaceae). Its chemical formula is $C_{13}H_{18}O_3N_2P_2$. Psilocybin is a crystalline solid that may have value in psychological medicine. Its effects are similar to those of mescaline.

(iv) **Cannabinoids (Products of Hemp Plant).** Cannabinoids are group of chemicals obtained from leaves, resin and inflorescence of Hemp plant, *Cannabis sativa* (= *Cannabis indica*). They interact with cannabinoid receptors present mainly in the brain. There are four types of cannabinoids.



Skeletal Structure of Cannabinoid molecule.



Leaves of *Cannabis sativa*.

(a) **Bhang.** It is fresh/dried leaves and flowering shoots of both male and female plants of *Cannabis sativa*. Bhang is generally taken orally (e.g., drink or in the form of pakora or tikki). It acts slowly.

(b) **Ganja.** It is the dried unfertilized female inflorescence of *Cannabis sativa*. It is smoked generally in cigarettes. It is more potent. Its effects are produced almost instantaneously.

(c) **Charas.** It is dried resinous extract from flowering tops and leaves of *Cannabis sativa*. It is most potent and smoked with tobacco. In some countries like America, charas is called **hashish**. Resin is obtained from the plant. The active principle in resin is **THC**, i.e., 9-tetrahydrocannabinol ($C_{21}H_{30}O_2$). It gives temporary feeling of well being and happiness.

(d) **Marijuana.** This is obtained from the dried flowers and top leaves of the female plants of *Cannabis sativa*. The most active ingredient of marijuana is delta-9 tetrahydrocannabinol (Delta-9 THC). It is smoked in cigarettes. A typical marijuana cigarette contains 0.5 to 1 gram of plant material. Although the usual THC concentration varies between 5 and

20 mg, concentration as high as 100 mg per cigarette has been detected. Marijuana may cause psychosis.

Products of Hemp plants raise the blood sugar level and increase the frequency of urination. They are relatively less harmful but regular intake of these products may lead to heroin like addiction. They bring about a state of well being (euphoria), excitement, sometimes uncontrolled laughter and dilation of pupil of eyes. They are very harmful if taken along with alcohol.

These days cannabinoids are also being abused by some sport persons.

Datura and Belladonna. Seeds of *Datura stramonium* and aerial parts of *Atropa belladonna* are misused for their hallucinogenic properties. However, even in slight excess, they can cause death.



Flowering branch of *Datura*.

Synthetic Hallucinogens

(i) **PCP (Phencyclidine Piperidine).** PCP is popularly called **angel dust** which is available as white granular powder. It has hallucinogenic, analgesic and anaesthetic properties. It is used by veterinary doctors to temporarily immobilise large animals.

(ii) **Methylenedioxy Methamphetamine (MDMA).** MDMA has CNS-excitant and hallucinogenic properties. It increases communication. MDMA has become popular in students under the name "ecstasy" drug.

Addiction and Dependence

Drugs are chemical formulations used to treat, prevent, diagnose or cure diseases or otherwise enhance physical and mental welfare. These drugs are normally used as medicines to help patients cope with mental illnesses like depression, insomnia and so on. But when drugs are taken for a purpose other than their normal clinical use in an amount, concentration or frequency that impairs one's physical, physiological and psychological function, it constitutes **drug abuse**. The prolonged use of drugs may lead to the dependence of body upon them. This state of psychological and physiological dependence of an individual to the intake of certain drug due to its repeated consumption on a periodic or continuous basis is called **drug addiction**. WHO (1964) has introduced the term **drug dependence** in place of drug addiction.

Types of drug dependence. It includes psychological dependence and physical (=physiological) dependence.

(i) **Psychological dependence.** It develops when the individual believes that normal condition of well being is achieved only through the actions of the drug.

(ii) **Physical dependence.** (= *physiological dependence*). It is a changed physiological state produced by repeated intake of a drug which becomes necessary to maintain physiological equilibrium. Discontinuation of the drug results in a characteristic withdrawal symptom. As the nervous system functions normally in the presence of the drug, the nervous system becomes adapted to the drug, so it is called 'neuroadaptation', while the term 'dependence' may be restricted to psychological dependence. Drugs producing physical dependence are

opiates, barbiturates and other depressants including benzodiazepines and alcohol. Amphetamines, Cocaine, Cannabis and LSD produce addiction but little/no physical dependence. On the other hand, drugs like Nalorphine (not used as analgesic, it was the first antagonist* introduced in 1951 which could reverse morphine action, later it was found to have agonistic** actions as well as) produce physical dependence without causing addiction in the sense that there is little drug seeking behaviour. Nalorphine does not cause psychological dependence.

Drug withdrawal Symptoms. If a drug dependent person stops taking a drug (abstinence), his body stops functioning normally (physical dependence) and he feels severe physical and psychological disturbances called withdrawal symptoms. They vary with the type and degree of addiction. (a) There is no *physical and physiological dependence on stimulants* (e.g., amphetamines, caffeine), therefore, there are no physical withdrawal symptoms. The dependence is only psychological which is exhibited by restlessness, anxiety and depression. (b) Withdrawal symptoms of *opiates* produce cramps, vomiting, running nose and epilepsy. Withdrawal symptoms of *heroin* are unpleasant. They include vomiting, nausea, diarrhoea, twitching, shivering, perspiration and muscular cramps. Sudden withdrawal of Barbiturates cause epilepsy.

These symptoms are so disturbing that one again starts taking drugs. Many drug addicts are afraid to leave the drugs because of the fear of these withdrawal symptoms. Some examples of drug withdrawal reaction are given below.

(i) Severe hypertension and sympathetic overactivity may occur just after discontinuing Clonidine.

(ii) Acute adrenal deficiency may occur due to sudden stoppage of corticosteroid treatment.

(iii) Frequency of seizures may increase by abrupt withdrawal of an antiepileptic.

(iv) Worsening of angina pectoris (a heart disease) may result from sudden stoppage of certain drugs.

These conditions can be minimized by gradual withdrawal of the drugs.

Symptoms of Drug Addicts

These include irritation, undue excitement, unprovoked violence, frequent mood changes, sleep disturbance, drowsy looks, pale looking eyes, loss of interest in work and studies, socially inactive, increased demands of money, staining of teeth because of smack use, poor memory and concentration, unexplained loss of weight, poor appetite, person may look inattentive and lost, looks weak and exhausted, concerned person may spend too much time in toilet or bathroom, his or her valuables get frequently stolen and gets up late in the morning.

Combinations of Drugs

Some drug addicts use mixtures of drugs to have immediate effect. Some of these combinations and their effects are given below.

* *Antagonist*. It prevents the action of an agonist on a receptor or the subsequent response, but does not have any effect of its own.

** *Agonist*. It activates a receptor to produce an effect.

Combination	Effects
1. Alcohol and other depressants, e.g., barbiturates	Dramatically increased depressant effect
2. Alcohol + Antihistamines (normally little or no sedative effect)	Marked drowsiness
3. Alcohol + Benzodiazepines	Rapid increase in sedative effect: often dramatic
4. Alcohol + Marijuana or Hashish impaired judgement	Decreased coordination, increased reaction time,
5. Alcohol + Aspirin	Increased risk of damage to gastric mucosa
6. Benzodiazepines + Barbiturates	Increased sedation
7. Amphetamine + Insulin	Decreased insulin effect
8. Nicotine + Cocaine	Increased cardiovascular effects
9. Cocaine + Antidepressants	Hypertension

Adolescence and Drug/Alcohol Abuse

Adolescence is the period of rapid growth and physical and mental development between childhood and adulthood (the period between 12–18 years). This period is from puberty (appearance of the first external signs of sexual maturation) to complete sexual maturity. Adolescence is marked by physical growth, development of reproductive organs, and changes in functioning of the neuroendocrine system.

Curiosity, excitement and need for adventure and experimentation are common causes which motivate young boys and girls towards drug and alcohol use. The first use of drugs or alcohol may be out of curiosity or experimentation but later on the child starts using to escape facing problems such as academics or examinations. Therefore, youngsters start taking alcohol and drugs. They want to be 'cool'. Television, movies, newspapers, advertisements, peer pressure, frustration, depression, feelings of independence, uncertain future, false belief, self identity etc. also help to promote drug and alcohol abuse and smoking. Unstable or unsupportive family structures have been seen to be associated with drug and alcohol abuse among adolescents.

Deaddiction

Treatment of drug addiction is called **deaddiction**. A close watch should be kept on the patients because mental confusion may occur any time during the treatment. Although proper medicines are given to the patient, yet the treatment is combined with supportive measures such as vitamin administration, restoration of electrolyte balance and proper hydration. A qualified doctor may be consulted.

The use of Acupuncture in the treatment of drug addiction is in practice in China and in some other countries.

Effects of Drug Abuse

1. **Nervousness and Psychosis.** Prolonged use of drugs leads to nervousness and psychosis. Drug addicts neglect their studies, duty and bring frustration not only for them-

selves but also for their family and community. They may lead to traffic and industrial accidents.

2. **AIDS and Hepatitis.** Many drug addicts inject these drugs in their blood vessels with previously used needles. Studies have shown that AIDS and Hepatitis-B are common in addicts using intravenous drugs.

3. **Misuse of Drugs by Certain Sports Persons.** Misuse of drugs is done by certain sports persons to increase their performance. The side effects of the use of anabolic steroids in females include masculinisation (males like features), increased aggressiveness, depression, abnormal menstrual cycles, enlargement of clitoris, deepening of voice; excessive hair growth on the face and body and mood swings. In males it includes reduction of size of the testicles, decreased sperm production, acne, potential for kidney and liver dysfunction, premature baldness, enlargement of prostate gland. In the adolescent male or female, stunted growth takes place.

4. **Impotency, Chromosomal Aberrations and Production of Abnormal Babies.** Continuous use of narcotics and stimulants cause impotency and chromosomal aberrations and production of abnormal babies.

5. **Effects on Kidneys.** Functions of kidney of drug abused persons are impaired and may be damaged.

6. **Victims of various diseases.** It is evident that prolonged use of drugs causes permanent damage to some organs and the body fails to work without the drugs. Therefore, the drug-users become victims of various diseases.

7. **Hormonal Changes.** Hormonal changes include an increase in **cortisol** levels, inhibition of **vasopressin**, reversible decrease in serum **thyroxine** and a more marked decrease in serum **triiodothyronine** (T_3). Thyroxine is also called **tetraiodothyronine** (T_4).

8. **Effect on Family.** The drug-users not only themselves suffer from the ill-effects of drug addiction, but also bring miseries to the entire family.

9. **Effect on Society.** Since drug abused persons get the supply of the drugs from illegal sources, they encourage smuggling and other associated illegal activities, resulting in several other social problems.

Prevention and Control

"Prevention is better than cure" is also true here. Tobacco, drugs/alcohol abuse are more during young age and during adolescence. Thus remedial measures should be taken well in time. In this regard the parents and teachers have a special responsibility. The following measures would be particularly useful for prevention and control of alcohol and drug abuse in adolescents.

1. **Avoid undue Peer Pressure.** Every child has his/her own choice and personality, which should be kept in mind. So a child should not be pressed unduly to do beyond his/her capacities, be it studies, sports etc.

2. **Education and counselling.** Education and counselling are very important to face problems, stresses, disappointments and failure in life. These should be taken as part of life. One should utilize a child's energy in some other activities like sports, music, reading, yoga and other extra curricular activities.

3. **Seeking help from parents and peers.** Whenever, there is any problem, one should seek help and a guidance from parents and peers. Help should be taken from close and trusted friends. This would help young to share their feelings of anxiety and wrong doings.

4. **Looking for Danger Signs.** If friends find someone using drugs or alcohol, they should bring this to the notice of parents or teacher so that appropriate measures would be taken to diagnose the illness and the causes. This would help in taking proper remedial steps or treatment.

5. **Seeking Professional and Medical helps.** Highly qualified psychologists, psychiatrists and de-addiction and rehabilitation programmes can help individuals who are suffering from drug/alcohol abuse. If such help is provided to the affected persons, with sufficient efforts and will power, the patient could be completely cured and lead normal and healthy life.

ADDITIONAL INFORMATION

- The Russian Biologist, **Ivanowsky (1892)** was the first to discover and demonstrate the presence of viruses in tobacco leaves suffering from mosaic disease.
- **Typhus.** It is caused by *Rickettsia prowazeki* and transmitted by fleas and lice. It is an acute, infectious disease which is also called **typhus fever**.
- Besides blood, HIV has been isolated from a number of body fluids and tissues such as semen, vaginal secretions, cervical secretion, breast milk, pericardial fluid and amniotic fluid.
- Landsteiner and Levine (1926) discovered the MN and P antigens.
- **National Antileprosy Day—30th January, world TB Day— 24th March; world AIDS Day— First December.**
- **Lentivirus.** Slow acting virus, e.g., HIV.
- Global programme against AIDS was launched on February 1, 1987.
- National AIDS Research Institute (NARI), Pune is famous for AIDS research.
- Bone marrow was transplanted on 23rd April 1983 to a leukemia patient at the Tata Memorial Hospital (famous for cancer treatment) in Mumbai in the first operation of its kind in India.
- **Father of Medicine— Hippocrates**
- **World Red Cross Day — 8th May.**
- **Antidote.** Substance used to counteract the effects of poisons, e.g., alkalies for acid poisoning.
- **World Health Day— 7th April.**
- **Tetrahydroisoquinolines (TIQ's)—** genetically related cause of alcoholism is also the formation of TIQ in the body.
- Non-rabies zone in India is Lakshadweep.
- **Prions** are proteinaceous infectious particles hence the name prion. **Stanley B. Prusiner** got the 1997 Nobel Prize for the discovery of prions.
- **Kuru** is a disease caused by a prion. **Carlton Gajdusek** was awarded the Nobel Prize in 1976 for his contributions on Kuru.
- Interferons were discovered by **Alick Isaacs** and **Jean Lindemann** in 1957.
- **Snell, Dausset** and **Benacerraf** were awarded the Nobel Prize for Medicine in 1980 for work on MHC and genetic control of immune response.
- **World Diabetes Day —14th November.**
- "White stripes on black body, white rings on hind legs" are seen in **Aedes** mosquito.
- **Malaria Day— 20th August.**
- The main reservoir of plague in India is *Tatera indica* (wild rat).
- The most accurate and specific test for rabies infection in **fluorescent antibody**.
- **August 29** is celebrated as the "Mosquito Day" because Sir Ronald Ross established mosquito-malaria relationship on August 29, 1897.
- **Father of ECG.** Einthoven, Nobel Prize in 1924.
- **Doctor's day** in India July 1.
- The pollutant mercury causes Minamata disease which is a neurological disease.
- Kerala has the dubious distinction of having the highest number of head and neck cancers in the world, according to the Amrita Institute of Medical Sciences (AIMS), Kochi.
- **Huggins** and **Peyton Rous** got the 1966 Nobel Prize in Physiology or Medicine for discovery of causes and treatment of cancer. Rous discovered first oncogenic virus—

Rous sarcoma virus (RSV) and hormonal treatment of prostate cancer.

- **Babesiosis** — rare protozoan disease caused by *Babesia microti*, transmitted to humans by tick bite (rarely by blood transfusion), symptoms include fever, chills, headache, sweats, pain in muscles and joints and nausea and vomiting.

- **Blastomycosis** — fungal disease, caused by inhalation of the conidia of *Blastomyces dermatitidis*, symptoms include inflammatory lesions of skin or lungs, bones, CNS, kidneys, liver and spleen.

- **World Rabies Day** — 28th September.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. What are the various public health measures which you would suggest us against infectious diseases ?
✓ Common preventive measures are (i) **Education**. People should be educated about the infectious diseases. (ii) **Vaccination**. People should get vaccination to avoid infection (iii) **Sanitation**. Proper sanitation can prevent spread of diseases. (iv) **Isolation**. The patient should be separated to avoid infection to others. (v) **Sterilization**. Patient's belongings should be sterilized (vi) **Eradication of vectors**. The breeding places of the vectors (if any) should be destroyed and adult vectors killed by suitable methods.
2. In which way has the study of biology helped us to control infectious diseases ?
✓ (i) The use of vaccines and immunisation programmes is due to advancements in biology. (ii) Biotechnology is helping to make new and safe vaccines. (iii) Discovery of antibodies and various other drugs have also enabled to treat infectious diseases.
3. How does the transmission of each of the following diseases take place ? (a) Amoebiasis (b) Malaria (c) Ascariasis (d) Pneumonia.
✓ (a) Amoebiasis --- faecal-oral route
(b) Malaria --- by the bite of female *Anopheles* mosquito
(c) Ascariasis --- through contaminated food and water
(d) Pneumonia --- from the sputum of the patient.
4. What measures would you take to prevent water-borne diseases ?
✓ Fresh and clean water should be taken. If water is contaminated it should be filtered before drinking. Water resources should be disinfected. One should not take pond's water.
5. Discuss with your teacher what does 'a suitable gene' means in the context of DNA vaccines.
✓ The term 'suitable gene' refers to that gene (specific segment of DNA) that will be modified in the host to produce specific protein to kill specific disease causing organisms.
6. Name the primary and secondary lymphoid organs.
✓ The primary lymphoid organs are bone marrow and thymus where immature lymphocytes differentiate into antigen sensitive lymphocytes. The secondary lymphoid organs are spleen, lymph nodes, tonsils, Payer's patches of small intestine and appendix.
7. The following are some well-known abbreviations, which have been used in this chapter. Expand each one to its full form : (a) MALT (b) CMI (c) AIDS (d) NACO (e) HIV
✓ (a) MALT— Mucosal-associated lymphoid tissue.
(b) CMI— Cell-mediated Immunity.
(c) AIDS— Acquired Immuno Deficiency Syndrome.
(d) NACO— National AIDS Control Organisation.
(e) HIV— Human Immunodeficiency Virus.
8. Differentiate between the following and give examples of each (a) Innate and acquired immunity (b) Active and passive immunity.
✓ Refer to the text (a) Differences between Innate Immunity and Acquired Immunity.
(b) Differences between Active Immunity and Passive Immunity.
9. Draw a well-labelled diagram of an antibody molecule.
✓ Refer to the text Fig. 8.20 Structure of an Antibody Molecule.
10. What are the various routes by which transmission of human immunodeficiency virus takes place ?
✓ (i) Sexual contact with infected person. (ii) Transfusion of contaminated blood and blood products.

- (iii) By sharing infected needles in case of intravenous drug abusers. (iv) From mother to child through placenta.
11. What is the mechanism by which AIDS virus causes deficiency of immune system of infected person?
✓ In infected person, HIV enters into macrophages where virus is replicated and gets incorporated with host cell's DNA with the help of enzyme RNA transcriptase. Infected host cells produce virus particles so that host's macrophages act as HIV factors. At the same time, HIV enters into helper T-lymphocytes (T_H) and replicates to form progeny virus. They again attack blood and helper T-lymphocytes. This disease in T-helper leads to deficient immunity in infected person.
 12. How is cancerous cell different from a normal cell ?
✓ Refer to the text Differences between Cancer Cells and Normal Cells.
 13. Explain what is meant by metastasis ?
✓ A phenomenon in which cancer cells spread to distant sites through body fluids to develop secondary tumor is called metastasis.
 14. List the harmful effects caused by alcohol/drug abuse.
✓ Refer to the text Alcohol Abuse and Drug Abuse.
 15. Do you think that friends can influence one to take alcohol/drugs. If you, how may one protect himself/herself from such an influence ?
✓ Yes, friends can influence for taking alcohol/drugs. Following measures can be taken (i) Avoiding undue peer pressure. (ii) Not taking undue pressure of failures beyond its threshold. (iii) Getting counselling from some counsellor. (iv) Seeking help from parents and peers. (v) Seeking medical help.
 16. Why is that once a person starts taking alcohol or drugs, it is difficult to get rid of this habit ? Discuss it with your teacher.
✓ Once a person starts taking alcohol or drugs, he becomes addict to these substances physically and mentally. Whenever, he tries to get rid of this habit, he shows unpleasant withdrawal symptoms and these include vomiting, diarrhoea, shivering, twitching, perspiration, abdominal and muscular cramps, etc.
So, it becomes difficult for a person to get rid of this habit.
 17. In your view, what motivates youngsters to take to alcohol or drug and how can this be avoided ?
✓ Youngsters generally take alcohol or drugs on the basis of the following factors. (i) Curiosity (ii) Pleasure (iii) To escape from the realities of life, to overcome frustrations and depressions. (iv) Friends pressure. (v) Desire of excitement. (vi) Desire to do more work. (vii) Unhappy married life. (viii) Monotony of daily life.
It can be avoided by the following ways. (i) Educating and counselling the child to face problems and stresses and accept disappointments and failure as a part of life. (ii) A child should not be pushed unduly to perform beyond his capacity. (iii) Parents and teachers should be alert about the activities of the child. (iv) Help can be taken from highly qualified psychologists and psychiatrists.

TEXT QUESTIONS

One Mark Questions (With Answers)

1. What is the role of histamine in inflammatory response ?
✓ **Histamine** is released by lymphocytes which cause the blood vessels to dilate.
2. Name the two chemicals released by damaged cells, that help in immunity.
✓ Histamine and prostaglandins
3. What are antigenic determinants ?
✓ Antigenic determinants are those sites on antigens that are recognised by antibodies and receptors present on B-cells and T-cells.
4. What is humoral immunity?
✓ It refers to immunity provided by the antibodies circulating in the body fluids(humors).
5. Name the drugs obtained from Hemp plant.
✓ Bhang, Ganja, Charas.

6. What is the source for drug L.S.D.?
✓ Ergot fungus
7. What are psychotropic drugs?
✓ The drugs that affect the central nervous system and alter the behaviour, perception and consciousness are called psychotropic drugs.
8. Name the drug to cure Leprosy.
✓ DDS (Diamino diphenyl sulphone).
9. What is neoplasm?
✓ The uncontrolled proliferation of cells (cancer) results in clones called neoplasm or tumour.
10. Name three diseases caused by alcohol.
✓ Alcoholic dementia, Alcoholic myopathy and Alcoholic cirrhosis.
11. Name the drugs of choice for withdrawal symptoms of alcohol.
✓ Benzodiazepines.
12. Recently chickungunya cases were reported from various parts of the country. Name the vector responsible. (CBSE 2008)
13. How do neutrophils act as a cellular barrier to pathogens in humans ? (CBSE 2008)
14. Why do sportspersons often fall a victim to cocaine addiction ? (CBSE 2008)
15. Explain what is meant by metastasis. (PSEB 2009)
16. How does the transmission of the disease Ascariasis take place ? (PSEB 2009)
✓ The eggs of the parasite are excreted along with the faeces of infected person which contaminate soil, water, plants etc. A healthy person acquires this infection through contaminated water, vegetables fruits etc.
17. What type of virus causes AIDS ? Name its genetic material. (CBSE 2009)
✓ AIDS is caused by the Human Immune Deficiency Virus (HIV). DNA is the genetic material
18. Suggest a method to ensure an anamnestic response in humans. (CBSE 2017)
✓ To ensure anamnestic or secondary immune response, dead or attenuated pathogens of a disease can be injected into a healthy person that can produce memory cells, i.e., vaccination.

Two Mark Questions (With Sample Answers)

1. How do killer T-cells work ?
✓ These cells attack directly and destroy antigens. In the process, these cells move to the site of invasion and produce chemicals that attract phagocytes and stimulate them so that they can feed more vigorously on antigens. They also produce substances that attract other T-cells.
2. Which type of immunity—active or passive is provided by vaccination ? Name the disease against which protection is provided by DPT vaccination.
✓ Active immunity is provided by vaccination. DPT—vaccination provides immunity against Diphtheria, Pertussis and Tetanus.
3. How whooping cough can be prevented ?
✓ The disease can be prevented by immunising all infants with whooping cough vaccine which is available singly or in combination as triple vaccine (i.e., DPT). Three doses of this vaccine should be given at intervals of one month starting from the age of 3 to 4 months.
4. What role macrophages play in providing immunity to humans ? (CBSE 2008)
5. What causes swelling of the lower limbs in patient suffering from filariasis ? (CBSE 2008)
6. Explain metastasis. Why is it fatal ? (CBSE 2009)
7. What measures would you take to prevent water borne diseases.
8. Recently a girl baby has been reported to suffer from haemophilia. How is it possible ? Explain with the help of a cross. (CBSE 2009)
9. Explain antibiotic resistance deserved in bacteria in the light of Darwinian selection theory.
10. (a) Name the lymphoid organ in humans where all the blood cells are produced.
(b) Where do the lymphocytes produced by the lymphoid organ mentioned above migrate and how do they affect immunity ? (CBSE 2009)
✓ (a) (i) Primary lymphoid organs;
(ii) Secondary lymphoid organs

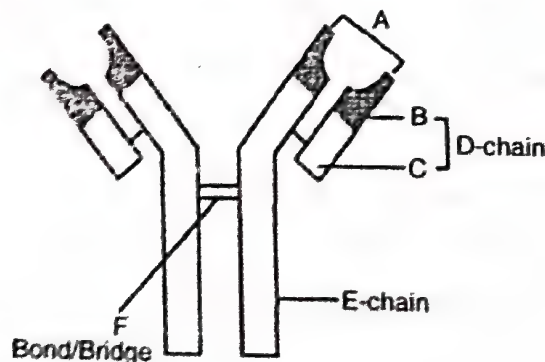
(b) Primary lymphoid organs are those that undergo maturation/differentiation into antigen-specific lymphocytes.

In bone marrow and thymus, and both provide the micro-environment for the development and maturation of beta-lymphocytes & lymphocytes.

Secondary lymphoid organs are spleen, lymph, nodes, tonsils etc. The lymphocytes interact with the antigen and proliferate to form a clone.

Antigens trapped in them activate the lymphocytes present in the lymph nodes and produce an immune response.

11. List the specific symptoms of typhoid. Name its causative agent. (CBSE 2009)
✓ *Salmonella typhi* is a pathogenic bacterium which causes typhoid fever in human beings. Sustained high fever (39° to 40°C), weakness, stomach pain, constipation, headache and loss of appetite are some of the common symptoms of this disease.
12. List four routes by which transmission of Human Immunodeficiency Virus (HIV) takes place.
13. Why is using tobacco in any form injurious to health ?
14. Give four differences between benign and malignant tumours.
15. How does malaria differ from chikungunya with reference of their vectors ? (CBSE 2010)
16. Why do normal cells not show cancerous growth ? (CBSE 2010)
17. (a) How does a vaccine affect immunity ?
(b) How can we get immunised against tetanus ? (CBSE 2010)
18. How do macrophages in the human body act as 'HIV factory' ? (CBSE 2010)
19. Why is the enzyme cellulase used for isolating genetic material from plant cells but not for animal cells? (CBSE 2010)
✓ DNA should be obtained in pure form for the action of restriction enzyme by treating the bacterial cell/plant cell or animal tissue with enzyme.
Bacteria – Lysozyme ; Plant cell – Cellulose ; Fungus – Chitinase
20. Name a molecular diagnostic technique to detect the presence of a pathogen in its early stage of infection. (CBSE 2010)
✓ Different viral and bacterial DNA in a host body can be detected by PCR and after this detected by ELISA test.
21. What is it that prevents a child to suffer from a disease he/she is vaccinated against ? Give one reason. (CBSE 2010)
✓ Hepatitis-B
In vaccination, a preparation of antigenic proteins of pathogen or inactivated/weakened pathogen are introduced into the body.
22. Name the two types of immune system in a human body. Why are cell mediated and humoral immunities so called ? (CBSE 2011)
23. Write the scientific names of the causal organisms of elephantiasis and ringworm in humans. Mention the body parts affected by them. (CBSE 2011)
24. Identify A, D, E and F in the diagram of an antibody molecule given below :



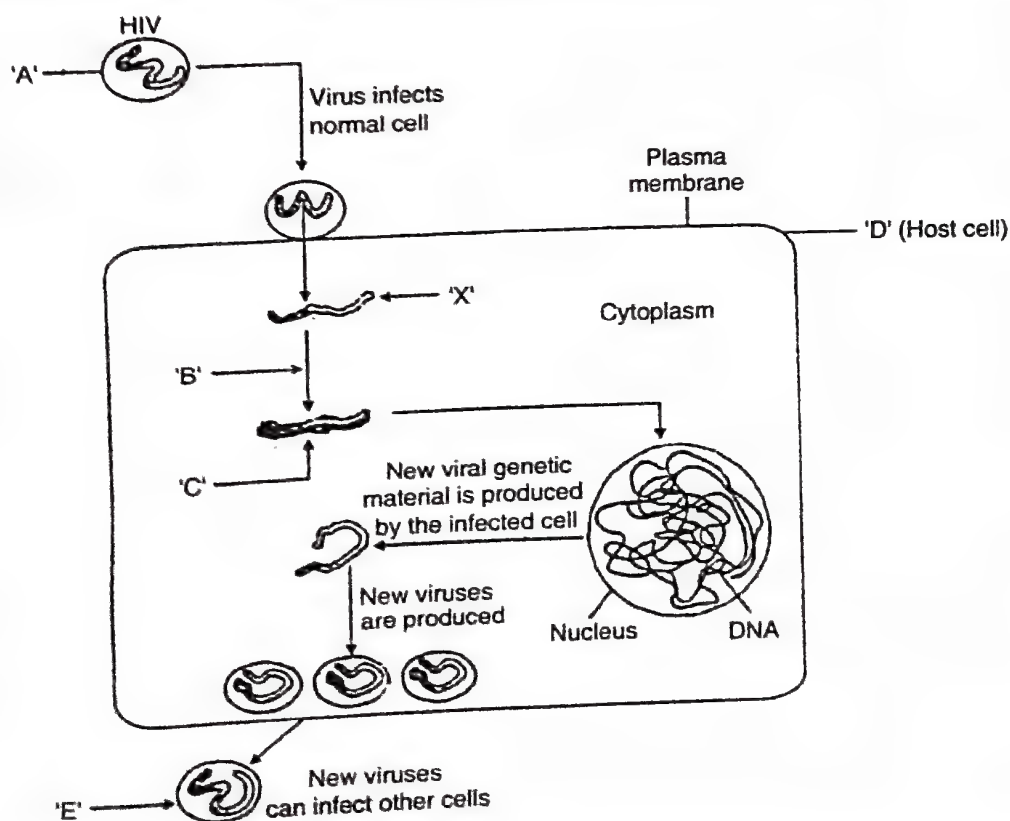
(CBSE 2011)

25. How do cellular barriers and cytokine barriers provide innate immunity in humans ? (CBSE 2011)
26. State the functions of primary and secondary lymphoid organs in humans. (CBSE 2011)
27. List the two types of immunity a human baby is born with. Explain the differences between the two types. (CBSE 2011)

28. Why are cancer patients often given α -interferon as part of the treatment? (CBSE 2014)
29. Name the causative organism of the disease amoebiasis. List three symptoms of the disease. (CBSE 2016)
30. Mention one application for each of the following :
 (a) Passive immunisation (b) Antihistamine (c) Colostrum (d) Cytokinin-barrier. (CBSE 2017)

Three Mark Questions

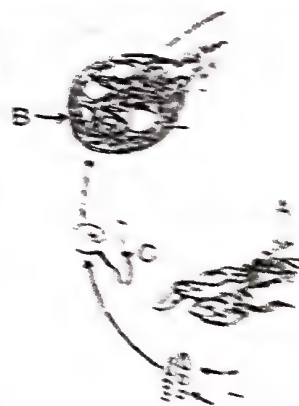
- Expand SCID and AIDS. Give any two differences between these conditions.
- Give one reason why lysozyme is considered an enzyme and not a hormone. How does it defend the body? Name any two secretions in human body which contain lysozyme.
- What are barbiturates and carcinogens?
- What is cancer? What are the three main types of cancer?
- Why is using tobacco in any form injurious to health? Explain. (CBSE 2008)
- Name the type of immunity that is present at the time of birth in humans. Explain any two ways by which it is accomplished. (CBSE 2008)
- A boy of ten years had chicken-pox. He is not expected to have the same disease for the rest of his life. Mention how it is possible. (CBSE 2009)
- What type of virus causes AIDS? Name its genetic material. (CBSE 2009)
- Explain the role of innate immunity in protection from infectious diseases.
- Define immunity. Describe different ways to develop immunity. Write the differences between active and passive immunity.
- What is immune system? What are its two main kinds? What is the role of β -cells and T-cells in body's defensive system?
- What is alcoholism? Describe the ill effects of alcohol on different parts of the body of an individual.
- What is Cancer? Explain three types of cancer. Name two danger signals of cancer. (PSEB 2010)
- A woman was tested positive for AIDS. Name the pathogen that infected her. How does this pathogen weaken her immune system? Explain. (CBSE 2010)
- Write the source and the effect on the human body of the following drugs :
 (i) Morphine, (ii) Cocaine, (iii) Marijuana. (CBSE 2011)
- Study the diagram showing replication of HIV in humans and answer the following questions accordingly:
 (i) Write the chemical nature of the coat 'A'.
 (ii) Name the enzyme 'B' acting on 'X' to produce molecule 'C'. Name 'C'.



- (iii) Mention the name of the host cell 'D' the HIV attacks first when it enters into the human body. (CBSE 2011)
- (iv) Name the two different cells the new viruses 'E' subsequently attack. (CBSE 2011)
17. Name the plant source of the drug popularly called "smack". How does it affect the body of the abuser? (CBSE 2012)
18. Certain types of leukocytes (WBCs) like polymorphonuclear leukocytes (PMNL-neutrophils) & natural killer cells in the blood are cellular barriers, which provide innate immunity in humans. (CBSE 2014)
19. A heavily bleeding and bruised road accident victim was brought to a nursing home. The doctor immediately gave him an injection to protect him against a deadly disease. Explain (CBSE 2015)
20. (a) It is generally observed that the children who had suffered from chicken-pox in their childhood may not contract the same disease in their adulthood. Explain giving reasons the basis of such an immunity in an individual. Name this kind of immunity. (CBSE 2015)
- (b) What are interferons? Mention their role.
21. (a) What precaution(s) would you recommend to a patient requiring repeated blood transfusion? (CBSE 2017)
- (b) If the advice is not followed by the patient, there is an apprehension that the patient might contract a disease that would destroy the immune system of his/her body. Explain with the help of schematic diagram only how the immune system would get affected and destroyed.
22. Name a human disease, its causal organism, symptoms (any three) and vector spread by intake of water and food contaminated by human faecal matter. Or
- (a) Why is there a fear amongst the guardians that their adolescent wards may get trapped in drug alcohol abuse? (CBSE 2017)
- (b) Explain 'addiction' and 'dependence' in respect of drug/alcohol abuse in youth. (CBSE 2017)

Five Mark Questions

1. (i) How and at what stage does *Plasmodium* enter into human body? (CBSE 2008)
- (ii) With the help of flow chart only show the stages of asexual reproduction in the life cycle of the parasite in the infected human. (CBSE 2008)
- (iii) Why does the victim show symptoms of high fever? (CBSE 2009)
2. Name the pathogen that causes amoebiasis in humans. Give the symptoms and the mode of transmission of this disease. (CBSE 2008)
3. (a) Why do the symptoms of malaria not appear immediately after the entry of sporozoites into the human body when bitten by female *Anopheles*? Explain. (CBSE 2009)
- (b) Give the specific name of the malarial parasite that causes malignant malaria in humans.
4. Name the type of cells the AIDS virus first enters into after getting inside the human body. Explain the sequence of events that the virus undergoes within these cells to increase their progeny. (CBSE 2009)
5. Explain the phenomenon of adaptive immunity with special reference to its properties, activation, clonal selection and its role in vaccination.
6. Expand ELISA. On what principle is ELISA test based? List two ways by which an infection can be detected by this test. (CBSE 2009)
7. (a) Name the Protozoan parasite that causes amoebic dysentery in humans. (CBSE 2012)
- (b) Mention two diagnostic symptoms of the disease.
- (c) How is this disease transmitted to others? (CBSE 2012)
8. Study a part of the life cycle of malarial parasite given below. Answer the questions that follows : (CBSE 12)
- (a) Mention the roles of 'A' in the life cycle of the malarial parasite.
- (b) Name the event 'C' and the organ where this event occurs.
- (c) Identify the organ 'B' and name the cells being released from it.
9. A person in your colony has recently been diagnosed with AIDS. People/ residents in the colony want him to leave the colony for the fear of spread of AIDS.
- (a) Write your view on the situation, giving reasons.
- (b) List the possible preventive measures that you would suggest to the residents of your locality in a meeting organised by you so that they understand the situation. (CBSE 2013)
- (c) Write the symptoms and the causative agent of AIDS.



Value Based Questions With Answers

1. Vipin visited his village with his grandfather. He saw larvae of mosquitoes in the water cooler, flower

pots and other stagnant water. He told his grandfather that mosquitoes are very harmful. Read the above passage and answer the following questions.

- (i) Why mosquitoes are harmful to mankind.
 - (ii) Name three diseases caused by mosquitoes.
 - (iii) What is the role of health workers in this case.
 - ✓ (i) Mosquitoes spread some disease in human beings.
 - (ii) Malaria, Chikungunya, Dengue.
 - (iii) They should educate the people about the harmfulness of mosquitoes.
2. Ramnath's father told to him that he should protect himself from dog, rat flea, tse tse fly, sandfly. Read the above passage and answer the following questions.
- (i) Which disease is caused by rabid dog ?
 - (ii) Which disease is caused by the bite of rate flea.
 - (iii) In which country tse tse fly is found and which disease is spread by it.
 - (iv) Name the disease spread by sand fly.
 - ✓ (i) Rabies (Hydrophobia)
 - (ii) Bubonic Plague
 - (iii) Africa, African sleeping sickness
 - (iv) Kala azar

Multiple Choice Questions

- (1) Japanese encephalitis is transmitted by (a) housefly (b) tse tse fly (c) sand fly (d) mosquito. (AFMC 2010)
- (2) Match the type of immunity listed in column I with the examples listed in column II. Choose the answer that gives the correct combination of alphabets of the two columns.

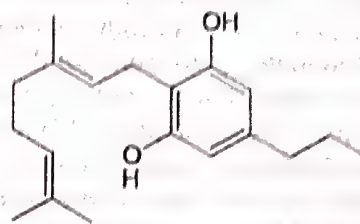
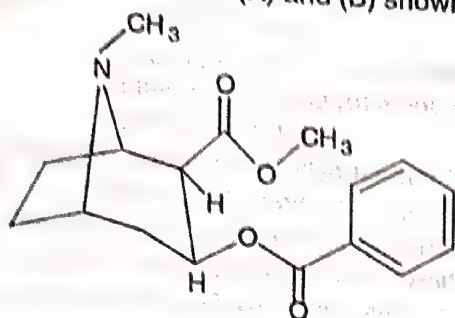
Column I Type of immunity	Column II Example
A Natural active	p Immunity developed by heredity
B Artificial passive	q From mother to foetus through placenta
C Artificial active	r Injection of antiserum to travellers
D Natural passive	s Fighting infections naturally
	t Induced by vaccination

- (a) A — s, B — t, C — q, D — r (b) A — t, B — s, C — r, D — p
 - (c) A — p, B — q, C — r, D — t (d) A — s, B — r, C — t, D — q (Karnataka CET 2010)
- (3) Which of the following is an autoimmune disease ? (a) Rheumatoid arthritis (b) Graves' disease (c) Hashimoto's disease (d) All of these. (MP PMT 2010)
 - (4) A patient is suspected to be suffering from Acquired Immuno Deficiency Syndrome (AIDS). Which diagnostic technique will you recommend for its detection ? (a) ELISA (b) MRI (c) ultra sound (d) WIDAL. (AIPMT (Prelims) 2011)
 - (5) At which stage of HIV infection does one usually show symptoms of AIDS ? (a) When the infecting retrovirus enters host cells (b) When viral DNA is produced by reverse transcriptase (c) When HIV replicates rapidly in helper T-lymphocytes and damages large number of these (d) Within 15 days of sexual contact with an infected person. (AIPMT (Prelims) 2011)
 - (6) The pathogen *Microsporium* responsible for ringworm disease in humans belongs to the same kingdom of organisms as that of (a) *Taenia*, a tapeworm (b) *Wuchereria*, a filarial worm (c) *Rhizopus*, a mould (d) *Ascaris* a round worm. (AIPMT (Mains) 2011)
 - (7) The 24 hour (diurnal) rhythm of our body such as the sleep-wake cycle is regulated by the hormone (a) calcitonin (b) prolactin (c) adrenaline (d) melatonin. (AIPMT (Mains) 2011)
 - (8) Read the following statement having two blanks (A and B). "A drug used for A patients is obtained from a species of the organism B. The one correct option for the two blanks is

- | | |
|----------------------|--------------------|
| A | B |
| (a) heart | <i>Penicillium</i> |
| (b) organ-transplant | <i>Trichoderma</i> |

- (c) swine flu *Monascus* (AIPMT (Mains) 2011)
 (d) AIDS *Pseudomonas* (West Bengal JEE 2011)
- (9) Which one of the following is related to humoral Immunity ? (a) T-lymphocyte (b) B-lymphocyte (c) I-lymphocyte (d) P-lymphocyte. (West Bengal JEE 2011)
- (10) Which one of the following cells is not a phagocytic cell ? (a) Macrophage (b) Monocyte (c) Neutrophil (d) Basophil. (West Bengal JEE 2011)
- (11) Which one of the following immunoglobulins is found as pentamer ? (a) IgG (b) IgM (c) IgA (d) IgE. (West Bengal JEE 2011)
- (12) Heroin is obtained by (a) acetylation of morphine (b) alkylation of cocaine (c) hydroxylation of morphine (d) methylation of benzodiazepines. (AMU Medical 2011)
- (13) Koch's postulates are not applicable for (a) fungi (b) protozoans (c) viruses (d) all of these. (AMU Medical 2011)
- (14) Hodgkin's disease is an example of (a) osteoma (b) carcinoma (c) leukemia (d) lymphoma. (AMU (Medical) 2011)
- (15) The Human Immunodeficiency Virus causes AIDS by (a) depleting CD_4^+ T-helper lymphocytes (b) increasing CD_4^+ T-helper lymphocytes (c) depleting CD_4^+ T-helper lymphocytes (d) depleting CD_4^+ T-helper erythrocytes. (AMU (Medical) 2011)
- (16) In hydridoma technology (a) B-cells are fused with myeloma cells (b) T-cells are fused with myeloma cells (c) B-cells are fused with T-cells (d) non of the above. (AMU (Medical) 2011)
- (17) During alcoholic fermentation by yeast two molecules of glucose produce (a) 2 molecules of ethanol + 2 molecules of CO_2 (b) 4 molecules of ethanol + 4 molecules of CO_2 (c) 6 molecules of ethanol + 6 molecules of CO_2 (d) 3 molecules of ethanol + 3 molecules of CO_2 . (AMU (Medical) 2011)
- (18) *Canabis sativa* is the source of (a) opium (b) LSD (c) marijuana (d) cocaine. (J & K CET 2011)
- (19) Alcoholism may leads to (a) skin cancer (b) liver cirrhosis (c) viral disease (d) eye infections. (J & K CET 2011; AMU 2011)
- (20) Sir Godfrey Hounsfield developed the diagnostic technique of (a) CT scanning (b) MRI (c) endoscopy (d) bronchoscopy. (J & K CET 2011)
- (21) 'Athlete's foot' is caused by (a) *Tinea pedis* (b) *Tinea capitis* (c) *Candida albicans* (d) *Rickettsia* (AMU 2012)
- (22) Immunoglobulins serving as mediators in allergic response are (a) IgE (b) IgD (c) IgM (d) IgA. (AMU 2012)
- (23) Which one of the following groups includes all sexually transmitted diseases ? (a) AIDS, syphilis, cholera (b) HIV, malaria, trichomoniasis (c) Gonorrhoea, hepatitis-B, chlamydiasis (d) Hepatitis-B, haemophilia, AIDS. (AMU 2012)
- (24) It is normally a rare cancer but became a marker for AIDS/HIV patients. (a) Squamous cell carcinoma (b) Retinoblastoma (c) Kaposi's sarcoma (d) Lukaemia. (AMU 2012)
- (25) What product of the immune system attaches to bacteria, making them easier to be eaten by white blood cells ? (a) Antigen (b) Haemoglobin (c) Antibody (d) MHC I molecule. (J & K CET 2012)
- (26) Cervical cancer can be caused by (a) *Chlamydia* sp. (b) Human papilloma virus (c) Herpes simplex virus (d) *Neisseria gonorrhoeae*. (J & K CET 2012)
- (27) How does vaccination work ? (a) The immune system produces antibodies which stay in the blood (b) Memory lymphocytes are produced. They remain in the body to fight off any future infection with the live pathogen (c) The dead pathogen stays in the body and constantly stimulates the immune system (d) All of the above. (J & K CET 2012)
- (28) Which one of the following is a correct match? (a) Filariasis – *Taenia solium* (b) Encephalitis – *Culex vishnui* (c) Malaria – *Phlebotomus* sp. (d) Kala-azar – *Anopheles stephensi*. (WB JEE 2012)
- (29) Identify the bacterium that appears violet after Gram staining. (a) *Salmonella enterica* (b) *Escherichia coli* (c) *Mycobacterium tuberculosis* (d) *Rhizobium meliloti*. (WB JEE 2012)
- (30) Humoral Immunity is mediated by (a) cytotoxic T-cell (b) plasma cell (c) eosinophil (d) neutrophil. (West Bengal JEE 2012)
- (31) Which one of the following is incorrect for 'atherosclerosis' ? (a) Constriction of arterial lumen reduces the blood flow (b) Loss of dilation ability of the arterial wall and its rupture (c) Cholesterol deposition at the inner wall of the artery (d) Proliferation of the vascular muscles. (West Bengal JEE 2012)
- (32) Which one of the following statements is correct with respect to immunity ? (a) Preformed antibodies

- need to be injected to treat the bite by a viper snake (b) The antibodies against small pox pathogen are produced by T-lymphocytes (c) Antibodies are protein molecules, each of which has four light chains (d) Rejection of a kidney graft is the function of B-lymphocytes. (CBSE PMT (Mains) 2012)
- (33) Identify the molecules (A) and (B) shown below and select the right option giving their source and use.



Molecule	Source	Use
(1) A - Cocaine	<i>Erythroxylum coca</i>	Accelerates the transport of dopamine
(2) B-Heroin	<i>Cannabis sativa</i>	Depressant & slows down body functions
(3) B-Cannabinoid	<i>Atropa belladonna</i>	Produces hallucinations
(4) A- Morphine	<i>Papaver somniferum</i>	Sedative and pain killer

- (34) Read the following four statements (1 – 4). (1) Colostrum is recommended for the new born because it is rich in antigens (2) Chikungunya is caused by a Gram negative bacterium (3) Tissue culture has proved useful in obtaining virus-free plants (4) Beer is manufactured by distillation of fermented grape juice.

How many of the above statements are wrong ? (a) Two (b) Three (c) Four (d) One.

(CBSE PMT (Mains) 2012)

- (35) Cells responsible for cell-mediated response are (a) T-cytotoxic cells (b) T-helper cells (c) B-cells (d) all of these. (AMU 2013)
- (36) HIV selectively targets (a) B- memory cells (b) B-effector cells (c) T-cytotoxic cells (d) T-helper cells. (AMU 2013)
- (37) A person may die due to allergic reaction or an anaphylactic shock which is characterized by (a) constriction of peripheral blood vessel (b) blood capillaries become highly permeable causing loss of fluid from the blood (c) drastic increase in the blood pressure (d) all of the above. (AMU 2013)
- (38) Infection of *Ascaris* usually occurs by (a) Tse-tse fly (b) mosquito bite (c) drinking water containing eggs of *Ascaris* (d) eating imperfectly cooked pork. (NEET 2013)
- (39) The appearance of chancre, rashes all over the body are the symptoms of (a) gonorrhoea (b) AIDS (c) syphilis (d) codon. (Karnataka CET 2013)
- (40) A disease sometimes found in persons above 40 years of age and is characterized by poor CNS coordination, forgetfulness and tremor of hands is (a) epilepsy (b) Alzheimer's disease (c) migraine (d) schizophrenia. (J & K CET 2013)
- (41) Which of the following is an auto-immune disease ? (a) AIDS (b) Haemophilia (c) Allergy (d) Rheumatoid arthritis. (J & K CET 2013)
- (42) The colostrum provides (a) naturally acquired active immunity (b) naturally acquired passive immunity (c) artificially acquired active immunity (d) artificially acquired passive immunity.

(Maharashtra CET 2014)

- (43) Myasthenia gravis is an example of (a) viral diseases (b) immunodeficient diseases (c) autoimmune diseases (d) allergic reactions. (AMU 2014)
- (44) Immunity that develops in the foetus after receiving antibodies from mother's blood through placenta is (a) naturally acquired active immunity (b) artificially acquired active immunity (c) naturally acquired passive immunity (d) artificially acquired passive immunity. (WB JEE 2014)
- (45) Passive immunity is (a) inherited from parents (b) acquired through first exposure to the disease (c) achieved directly through ready-made antibodies (d) achieved through vaccination. (J&K CET 2014)
- (46) Widal test is done to confirm (a) malaria (b) typhoid (c) pneumonia (d) jaundice. (J & K CET 2014)
- (47) 'Ringworm' a common infectious disease in man causing dry scaly lesions on the skin and scalp, is caused by (a) bacteria (b) round worms (c) filarial worms (d) fungi. (AMU 2014)



- (48) Which is the particular type of drug that is obtained from the plant whose one flowering branch is shown here? (a) Hallucinogen (b) Depressant (c) Stimulant (d) Pain-killer. (AIPMT 2014)
- (49) Which of the following immunoglobulins does constitute the largest percentage in human milk? (a) IgD (b) IgM (c) IgA (d) IgG. (AIPMT 2015)
- (50) Antivenom injection contains preformed antibodies while polio drops that are administered into the body contain (a) Harvested antibodies (b) Gamma globulin (c) Attenuated pathogens (d) Activated pathogens. (NEET-I-2016)
- (51) Asthma may be attributed to (a) Allergic reaction of the mast cells in the lungs (b) Inflammation of the trachea (c) Accumulation of fluid in the lungs (d) Bacterial infection of the lungs. (NEET-I-2016)
- (52) Transplantation of tissues/organs fails often due to non-acceptance by the patient's body. Which type of immune response is responsible for such rejections? (a) Cell-mediated immune response (b) Hormonal immune response (c) Physiological immune response (d) Autoimmune response. (NEET 2017)
- (53) MALT constitutes about _____ percent of the lymphoid tissue in human body. (a) 20% (b) 70% (c) 10% (d) 50%. (NEET 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—

- (a) If both A and R are true and R is the correct explanation of A
 (b) If both A and R are true and R is not the correct explanation of A
 (c) If A is true but R is false
 (d) If both A and R are false.

- Assertion : An antibody is a protein molecule made by the lymphocytes.
Reason : An antibody binds to a specific foreign antigen and neutralizes its odd effects.
A B C D
- Assertion : Phagocyte cells digest microbes and debris.
Reason : Natural Killer cells destroy virus-infected cells and tumour cells.
A B C D
- Assertion : Lymphocytes arise from bone marrow and present in the blood, lymph and serve as natural killer cells.
Reason : Lymphocytes migrate to thymus, where they develop into T cells and begin to mature.
A B C D
- Assertion : Secondary immune response is quicker and stronger than the primary one.
Reason : Memory cells conversant with the recoming antigens are ready to combat the invaders.
A B C D

ANSWERS

Multiple Choice Questions

- (1) —d (2) —d (3) —d (4) —a (5) —c (6) —c (7) —d (8) —b (9) —b (10) —d
 (11) —b (12) —a (13) —c (14) —d (15) —a (16) —a (17) —b (18) —c (19) —b (20) —a
 (21) —a (22) —a (23) —c (24) —c (25) —c (26) —b (27) —b (28) —b (29) —c (30) —b
 (31) —b (32) —a (33) —d (34) —b (35) —a (36) —d (37) —b (38) —c (39) —c (40) —b
 (41) —d (42) —b (43) —c (44) —c (45) —c (46) —b (47) —d (48) —a (49) —c (50) —c
 (51) —a (52) —a (53) —d

Assertion and Reason Type Questions

- (1) —B (2) —B (3) —A (4) —A

Due to rapid increase in human population of the world, increase of food production is a major necessity. **Animal husbandry** and **plant breeding** have to play a major role to increase food production. New techniques, such as embryo transfer technology and tissue culture, are of great importance in increasing food production because other things depend upon it.

ANIMAL HUSBANDRY

Animal husbandry is a branch of agriculture which deals with the feeding, breeding, housing and health care of livestock for getting maximum benefits.

Livestock refers to farm animals (domesticated animals) such as cow, sheep, etc. kept by humans for a useful commercial purpose.

When we use the word "Animal" in animal husbandry, we mean only those domesticated animals which are reared mostly for economic or for recreation purposes, such as cattle, buffalo, sheep, goat, camel, pig, horse, etc. It also includes poultry farming and fisheries. Fisheries include rearing, catching, selling, etc. of fish, molluscs (shell fish) and crustaceans (Fresh water prawn— *Palaemon*, Crabs, etc.). Since long time, animals like bees and silk-worm, have been used by humans. Livestock has been used by humans for products like milk, eggs, meat, wool, silk, honey, etc.

More than 70 percent of the world livestock population is in India and China. But it is interesting to note that the contribution to the world farm produce is only 25 percent. Hence in addition to old practices of animal breeding and care, new techniques have to be used to improve quality and productivity.

The word '**husbandry**' means the management of domestic affair. The term used in connection with animal husbandry includes proper feeding, breeding, health care, housing, etc.

Role of Animal Husbandry in Human Welfare

1. **Dairy Products.** Mammalian livestock can be used as a source of milk and dairy products such as yoghurt, cheese, butter, ice cream, etc.
2. **Meat.** It is the production of a useful form of dietary protein and energy.
3. **Land management.** The grazing of livestock is sometimes used as a way to control weeds and undergrowth. For example, in areas prone to wild fires, goats and sheep are set to graze on dry shrub which reduces the risk of fires.
4. **Fibre.** Livestock produce a range of fibres/textiles. For example, sheep and goats produce wool and deer and sheep can make leather.

*Livestock — same in both singular and plural.

5. **Labour.** Animals such as horses, donkey and yaks can be used for mechanical energy. Prior to steam power, livestock were the only available source of non-human labour. They are still used for this purpose in many places of the world, including ploughing fields, transporting goods and military functions.

6. **Fertilizer.** Manure can be spread on fields to increase crop yields. This is an important reason why historically, plant and animal domestication have been intimately linked. Manure is also used to make plaster for walls and floors and can be used as a fuel for fires. The blood and bones of animals are also used as fertilizer.

Management of Farm and Farm Animals

Management is the art and science of combining ideas, facilities, processes, materials and labour to produce and market a worthwhile product or service successfully. Some of the management procedures in various animal farm systems are described below.

(1) Dairy Farm Management

Dairying is the management of animals for milk and its products for human consumption. Cows, buffaloes, goats and sheep are the animals that we would expect in a dairy. Cows and buffaloes generally give more milk than goats and sheep. The yellow colour of cow milk is due to the carotene. Buffalo milk does not contain carotene. Ghee from cow fed on an abundant green fodder is more yellow than when fed on dry food.

In dairy management, the people deal with **processes** and **systems** that increase yield and improve quality of milk. These are described below.

1. **Four essential methods for livestock improvement.** These are breeding, weeding, feeding and heeding. (i) Both the male and female animals selected for *breeding* should be of superior quality. (ii) *Weeding* aims that uneconomic animals must be prevented from reproducing. (iii) *Feeding* is also very important for animals. Each animal should be fed on a balance ration. (iv) *Heeding* (pay attention to) implies good animal management and general supervision including housing care and maintenance of proper cleanliness and hygiene.

2. **Health Care.** According to WHO 'health' is the state of complete physical, mental and social well being and not merely the absence of disease. A healthy animal eats, drinks and sleeps well regularly. Therefore, good health is important.

3. **Suitable Environmental Conditions.** Adequate ventilation, suitable temperature, sufficient light, water, air and well-drained housing accommodation should be provided.

4. **Resistance to Diseases.** If the animal is well looked after, the resistance to diseases develops and animal is protected from the diseases.

5. **Regular Inspections.** The above mentioned measures would of course, require regular inspections, with proper record keeping. Regular visits by veterinary doctor would be necessary.

Thus the productive potentialities of live stock are controlled by three principle factors; (i) genetic make up (ii) nutrition and (iii) environment including the climatic conditions. "Father of white revolution in India" is **Verghese Kurein**.

(2) Poultry Farm Management

The word 'poultry' is used for birds which can be raised under domestication for economic purpose. The term applies to chickens, turkeys, ducks, geese, swans, guinea fowls, pigeons, peafowls and quails. In our country, it mainly means chickens, domesticated for eggs and meat. Ducks are also domesticated but to a much less extent.

Poultry farm management includes the following components.

1. **Selection of Disease Free and Suitable Breeds.** Selection of breeds is the most important aspect. The breed should be disease free and suitable to the environmental conditions. The most common egg-type variety used for commercial production throughout the world is **Single Comb White Leghorn** and its various strains. The meat type stocks mainly originated from **Plymouth Rock, Cornish** and **New Hampshire** breeds of fowls.

2. **Brood House.** Brooder house should be crowd-free, rain proof and protected from predators. It should have windows with wire mesh for adequate ventilation.

3. **Sanitation and Hygiene.** The house should be cleaned and disinfected. Good drainage system is essential to keep the poultry yard clean.

4. **Care of Chicks During Brooding.** On the arrival of chicks sweet water (gur 50 g/ litre) is given. The feed in the form of maize *dalia* should be given in the first 24–28 hours, but later on complete chick feed should be added to the feeders. Additional vitamins should be given in water during the first week.

5. **Feed Management.** Feeding constitutes the major management concern in egg and meat production. The groups of nutrients are proteins, carbohydrates, fats, minerals and vitamins.

6. **Light Management.** Light is essential for high egg production. 14 to 16 hours of light including daylight is required for optimum production.

7. **Summer Management.** The birds have thick feather covering and do not have sweat glands. *The birds can withstand cold, but are more sensitive to heat.*

8. **Winter Management.** Try to maintain the temperature above 15.5° C. Thus right temperature should be maintained.

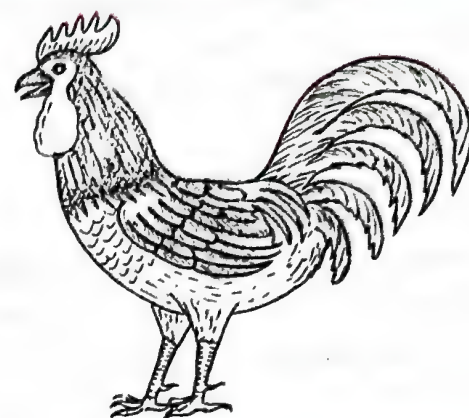


Fig. 9.1. A Leghorn.

Breeds. Some breeds of Chicken are given below.

Desi (Indigenous Breeds)

Aseel
Chittagong or Malay
Ghagus
Busra
Tenis
Naked Neck
Lolab
Karaknath
Titri
Tellicherry
Danki
Kalahasti
Gallus

American Breeds

Plymouth Rock
Wyandotte
Rhode Island red
Jersey black giant
New Hampshire

Asiatic Breeds

Brahma
Cochin
Langshan

English Breeds

Australorp
Cornish
Dorking
Orpington
Sussex
Red Cap

Mediterranean Breeds

Leghorn
Minorca
Ancona
Andalusian (blue)

Diseases of Poultry. The following are some of the important disease of the poultry.

1. Viral Diseases

(i) **Ranikhet Disease (New Castle Disease)** is caused by *Paramyxovirus*, characterized by coughing, sneezing and often droopiness.

(ii) **Marek's Disease (M. D.)** is caused by *Herpes virus*, paralysis is one of the major clinical signs.

(iii) **Fowl Pox** is caused by *Pox virus*, lesions commonly appear on the unfeathered parts of head and legs.

(iv) **Avian Encephalomyelitis (AE)** is caused by *Picoma virus*, tremors of the head and neck followed by paralysis and death.

(v) **Bird Flu** is caused by a virus H_5N_1 , resembles influenza. The virus enters the man through chicken. All incontact and sick birds must be destroyed.

2. Bacterial Diseases

(i) **Pullorum Disease (Bacillary White Diarrhoea)** is caused by *Salmonella pullorum*. The clinical signs are depression anorexia (lack of interest), drooping wings, respiratory disturbances and whitish diarrhoea.

(ii) **Infectious Coryza** is caused by *Haemophilus paragallinarum*, characterized by discharge from the nostrils and eyes, facial swelling and coughing.

(iii) **Spirochaetosis (Tick Fever)** is caused by a spirochaete, *Borrelia anserina*, transmitted by a tick (*Argas persicus*), characterized by anorexia, depression, cyanosis of the head and anaemia.

3. Fungal Diseases

(i) **Aspergillosis (Brooder Pneumonia)** is caused by a fungus *Aspergillus fumigatus*, characterized by dyspnoea (difficulty in breathing), dullness, weight loss and anaemia.

(ii) **Mycosis (Thrush)** is caused by a yeast *Candida albicans*. It affects mostly upper portion of the digestive tract. The affected young chickens become dull and are found at resting and sleeping stage for a long time. Mycosis is also called **candidiasis**.

4. Protozoanal Disease

Coccidiosis is caused by a group of protozoans called *coccidia* (e.g., genus *Eimeria*) which affect parts of intestine. The different species of coccidia affect different parts of the intestine. There are ruffled feathers, paleness of combs and wattles, loss of appetite, stunted growth, drop in egg production, diarrhoea.

5. Nutritional Deficiency Diseases

(i) **Encephalomalacia** is due to deficiency of Vitamin E. There is poor coordination of gait (a way of walking) due to brain degeneration. There is poor hatchability.

(ii) **Perosis** is due to deficiency of manganese in ration. There is enlargement of tibiotarsal joint, twisting and bending of end of tibia.

Advantages of Poultry Farming. Poultry farming has the following advantages.

1. **Food.** It provides eggs and meat which are highly nutritious foods. They are a rich source of animal protein, minerals, right kind of fat and vitamins (A, B and D) for good health. Unfertilized eggs are called "vegetarian eggs".

2. **Economic Uplift.** By selling the eggs and meat of these birds, the farmers become economically better. Poultry farming provides employment to a large number of people.

3. **Manure.** The faecal matter of birds form a rich manure which increases the fertility of soil. It increases crop yields.
4. **Feathers.** Feathers of the birds are useful.
5. **Recreation.** The birds of poultry are also a means of recreation. Coloured chickens give pleasure look. Cock-fighting is popular in some people.

Animal Breeding

Meaning. A group of animals related by descent and similar in most characters like general appearance, features, size, configuration, etc. are said to belong to a 'breed'. Animal breeding is producing improved breeds of domesticated animals by improving their genotypes through selective mating.

Objectives of Animal Breeding. The main objectives of animal breeding are : (i) improved growth rate, (ii) increased production of milk, meat, egg, wool, etc., (iii) superior quality of milk, meat, eggs, wool, etc., (iv) improved resistance to various diseases, (v) increased productive life, and (vi) increased or, atleast, acceptable reproduction rate.

Methods of Animal Breeding. Two methods of animals breeding are : inbreeding and outbreeding, based mainly on breeding work with cattle.

1. **Inbreeding.** When breeding is between animals of the same breed for 4–6 generations, it is called inbreeding. Inbreeding may be explained by taking an example of cows and bulls. Superior cows and superior bulls of the same breed are identified and mated. The progeny obtained from such mating are evaluated and superior males and females are identified for further mating. A **superior female**, in the case of cattle, is the cow that produces more milk per lactation. On the other hand, a **superior male** is that bull, which gives rise to superior progeny as compared to those of other males. As the homozygous purelines developed by Mendel as described in Chapter 5, a similar strategy is used for developing purelines in cattle as was used in case of peas. Inbreeding, as a rule, increases **homozygosity**. Thus inbreeding is necessary if we want to develop a pureline in any animal. Inbreeding exposes harmful recessive genes that are eliminated by selection. It also helps in accumulation of superior genes and elimination of less desirable genes. But continued inbreeding reduces fertility and even productivity. This is called **inbreeding depression**. In this condition, the selected animals of the breeding population should be mated with superior animals of the same breed but unrelated to the breeding population. This often helps in restoring fertility and yield.

2. **Outbreeding.** Outbreeding is the breeding between the unrelated animals which may be between individuals of the same breed (but having no common ancestors) or between different breeds (cross breeding) or different species (interspecific hybridization).

(i) **Outcrossing.** It is the mating of animals within the same breed but having no common ancestors on either side of their pedigree up to 4–6 generations. The offspring of such a cross is called as an outcross. Outcrossing is the best breeding method for animals that are below average in productivity in milk production, growth rate in beef cattle, etc. Sometimes only one outcross helps to overcome inbreeding depression.

(ii) **Cross-breeding.** In cross-breeding superior males of one breed are mated with superior females of another breed. Many new animal breeds have been developed by this strategy. It gives better breeds. Cows of an inferior breed may be mated to bulls of a superior breed to get better progeny. *Hisardale* is a new breed of sheep developed in Punjab by crossing Bikaneri ewes and Marino rams.

(iii) **Interspecific Hybridisation.** In this approach, male and female animals of two different species are mated. The progeny obtained from such a mating are usually different from both the parental species. But in some cases, the progeny may combine desirable characters of both the parents. Mule is produced from a cross between female horse (mare) and male donkey. Mules are harder than their parents and are well suited for hardwork in mountainous regions.

Controlled Breeding Experiments. These are carried out using artificial insemination and Multiple Ovulation Embryo Transfer Technology (MOET).

(i) **Artificial Insemination (AI).** The semen of superior male is collected and injected into the reproductive tract of the selected female by the breeder. The semen can be used immediately or can be frozen for later use. When a bull inseminates a cow naturally approximately 5 to 10 billion sperms are deposited in the vagina. However, when semen is deposited artificially, considerably fewer sperms are required to achieve conception. Therefore, artificial insemination is very economical. The spread of certain diseases can be controlled by this method.

(ii) **Multiple Ovulation Embryo Transfer Technology (MOET).** In this method, hormones (with FSH-like activity) is given to the cow for inducing follicular maturation and super ovulation instead of one egg, which they usually give per cycle, they produce 6–8 eggs. The cow is either mated with a best bull or *artificially* inseminated. The embryos at 8–32 cell stage are recovered and transferred to surrogate mothers. The genetic mother is available for another super ovulation. MOET has been done in cattle, sheep, rabbits, buffaloes, mares, etc. High milk giving breeds of females and high quality (lean meat with less lipid) meat-giving bulls have been bred successfully to obtain better breed in a short time.

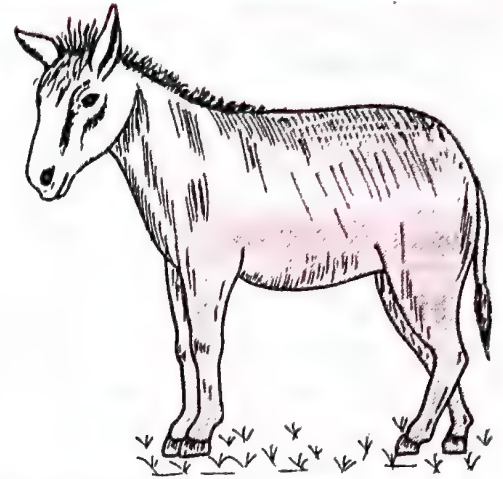


Fig. 9.2. Mule.

Examples of Some Breeds of Domesticated Animals

1. Cattle (*Bos indicus*)



Fig. 9.3. A Sahiwal cow. Note the well developed udder with good-sized teats.

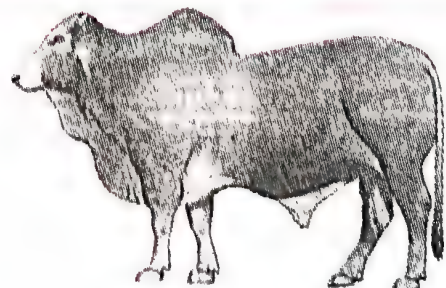


Fig. 9.4. A Sahiwal bull.

Breeds of Cattle. The cattle breeds are classified into three groups.

(i) **Milch Breeds.** The cows of these breeds are good milk producing, however, bullocks are of poor quality.

(ii) **Draught Breeds.** The bullocks of these breeds are good for working but cows are poor milk producers.

(iii) **General utility Breeds (Dual-purpose Breeds).** The cows of these breeds are good milk producers and the bullocks are good draught animals. Lactation in sterile cows is induced by **stibesterol**.

Table 9.1. Some Breeds of Indian Cattle

<i>Milch Breeds</i>	<i>Distribution</i>
1. Gir	Gujrat, Rajasthan
2. Sahiwal	Punjab, Haryana, Uttar Pradesh
3. Deoni	Andhra Pradesh
4. Red Sindhi	Andhra Pradesh
<i>Draught Breeds</i>	
1. Malvi	Rajasthan, Madhya Pradesh
2. Nagori	Delhi, Haryana, Uttar Pradesh, Rajasthan
3. Hallikar	Karnataka
4. Kangayam	Tamil-Nadu and other parts of south India
5. Kherigarh	Kheri district of Uttar Pradesh.
6. Bachaur	Sitamarhi district of Bihar
7. Khillari	Maharashtra
8. Amritmahal (Karnataka CET 2013)	Karnataka (former princely state of Mysore)
9. Ponwar	Foothills of Himalayas
10. Siri	Darjeeling in West Bengal, Sikkim
11. Bargur	Karnataka (Mysore type cattle)
12. Kenkatha	Western India
<i>General Utility Breeds (Dual Purpose Breeds)</i>	
1. Hariana	Haryana, Punjab, Bihar, Madhya Pradesh, Gujrat
2. Ongole (Nellore)	Andhra Pradesh
3. Kankrej	Gujarat
4. Tharparkar	Rajasthan, Gujrat
5. Mewati (Kosi)	Alwar & Bharatpur districts of Rajasthan
6. Rathi (Rath)	Alwar and Bikaner districts of Rajasthan
7. Dangi	Ahmednagar and Nasik districts of Maharashtra
8. Nimari	Nimar tract of Madhya Pradesh and the adjoining parts of Maharashtra
9. Gaolao	Maharashtra, Madhya Pradesh
10. Krishna valley	Valley Along the river Krishna—Karnataka, Maharashtra, Andhra Pradesh

New Breeds. (1) **Karan Swiss.** This breed has been evolved at the National Dairy Research Institute, Karnal in Haryana, by breeding the Sahiwal cows with the semen of Brown Swiss bulls imported from U.S.A.

(2) **Sunandini.** This breed originated in Kerala by crossing the local non-descript cattle with Jersey, Brown Swiss and Holstein-Friesian breeds.

(3) **Karan Fries.** The breed has got its origin at the National Dairy Research Institute Karnal, out of crossing between Tharparkar and Holstein Friesian.

Some exotic (foreign) breeds of cattle (*Bos taurus*) that are used for cross-breeding purpose in India.

Name	Country of origin
1. Jersey	Island of Jersey in English channel
2. Holstein-Friesian	Holland
3. Ayrshire	Scotland
4. Brown Swiss	Switzerland

Diseases of Cattle. *Viral* — Rinderpest (Cattle plague), Foot and Mouth Disease, *Bacterial* — Anthrax, Mastitis. *Protozoanal*— Babesiosis. Disease caused by Prion—Mad Cow Disease.

2. Indian Buffalo (*Bubalus bubalis*)

Breeds of Indian Buffaloes. There are *seven breeds* of buffaloes in India. The best known breeds of Indian buffaloes are the Murrah, Jaffarabadi, Nili, Bhadawari and Surti.

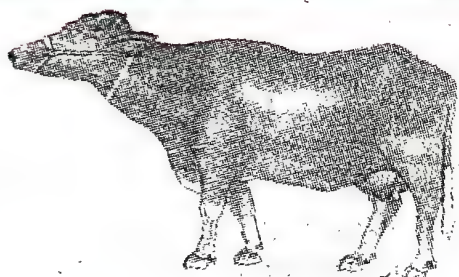


Fig. 9.5. A Murrah Female Buffalo.



Fig. 9.6. A Murrah Male Buffalo.

Table 9.2. Some Breeds of Indian Buffaloes

1. Murrah	Punjab, Haryana, Uttar Pradesh
2. Bhadawari	Uttar Pradesh, Madhya Pradesh
3. Jaffarabadi	Gujarat
4. Surti	Rajasthan, Gujrat
5. Mehsana	Gujarat
6. Nagpuri or Ellichpuri	Central and South India
7. Nili Ravi	Punjab, Haryana

3. Sheep (*Ovis aries*)

Sheep is a gregarious, ruminant often horned mammal.

Some Exotic Breeds of Sheep

- (1) Merinos. It is the *most popular fine wool breed*.
 (2) Rambouillet (3) Suffolk (4) Dorset (5) Corriedale
 (6) Southdown (7) Lincoln and (8) Leicester.

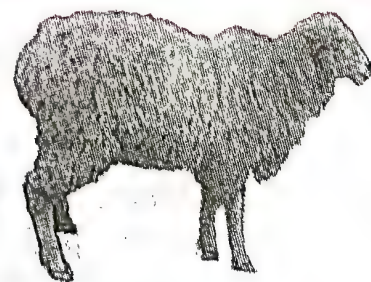


Fig. 9.7. Nali Sheep.

Table 9.3. Some Indian Sheep Breeds

I. Northern Temperate Region		III. Southern Region	
1. Gaddi		1. Deccani	
2. Bhakarwal.		2. Nellore	
3. Rampur Bushair			
4. Gurez			
II. Northern-Western Arid and Semi-arid Region		IV. Eastern Region	
1. Nali		1. Chhota Nagpuri	
2. Lohi		2. Shahabadi	
3. Marwari		3. Ganjam	

4. Goat (*Capra capra*)

Goat is called the poor man's cow. The goat is usually hollow-horned and bearded ruminant mammal. It has strong smelling power. It can readily adapt to almost any climate.

Exotic Breeds of Goats. (1) Alpine. (2) Toggenberg. (3) Saanen. (4) Nubian and (5) Angora.

Pashmina wool is obtained from the mountain goat. This animal is found in Ladakh and Tibet.

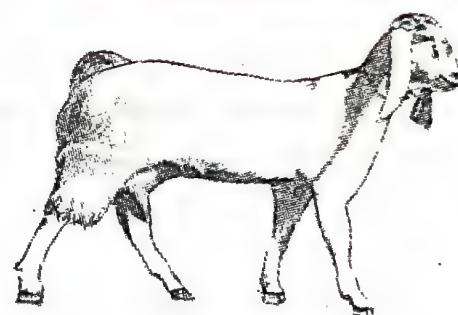


Fig. 9.8. A female Jamunapari goat.

Table 9.4. Some Indian Goat Breeds.

Northern Temperate Region		Southern Region	
1. Gaddi	2. Kashmiri Pashmina	1. Malabari	2. Surti
3. Changthangi	4. Chegu	3. Sangamneri	4. Osmanabadi
North-Western Arid and Semi-arid Region		Eastern Region	
1. Marwari	2. Sirohi	1. Bengal	2. Ganjam
3. Beetal	4. Jamunapari		

The Government of India has set up Central Institute for Research on Goats at Makhdood near Mathura in Uttar Pradesh.

Africa and India have the largest goat population.

5. Pigs (*Sus scrofa*)

Pig is also called **swine** or **hog**. It is an omnivorous, non-ruminant, gregarious mammal. The European breeds of domestic swine were derived from the local wild pig, *Sus scrofa*, whereas the breeds in the far Eastern parts of the globe were derived from another wild pig, *Sus vittatus*. The modern breeds of pig evolved from different crossings between the two original types. The present day domestic pig, *Sus domesticus* is the result of several years of evolution through gradual domestication.

Breeds of Pig. There are about 60 recognised breeds of domestic pigs in the world.

Indian Breeds. Large-White Yorkshire Boar, Large-White Yorkshire Sow, Middle White Yorkshire Boar, Middle White Yorkshire Sow.

Exotic Breeds. Berkshire, Large White Yorkshire, Landrace, Middle White Yorkshire, Hampshire, Tamworth and Wessex.

Wallows. Pigs have poor heat-regulating mechanism as they sweat only on the snout, because they have very few sweat glands.

6. Horses (*Equus caballus*)

Table 9.5. Important breeds of Indian Horses

Name	Regions
1. Kathiawari	Rajasthan and Gujarat
2. Marwari	Rajasthan
3. Bhutani or Bhutia	Punjab and Bhutan
4. Manipuri	North-eastern mountains
5. Spiti	Himachal Pradesh
6. Zanskari	Ladakh

7. Donkeys (*Equus asinus*)

There are two breeds of donkeys in India (i) Small, dark grey and large, light grey. They occur in most parts of India. (ii) White donkey are also called wild ass. They occur in Rann of Kutch.

8. Mules (Fig. 9.2)

A mule is a hybrid of male donkey (Jack) and a female horse (mare). It inherits size and intelligence from the horse and firm footedness, great tolerance and ability to live on rough food from the donkey. However, with all its hybrid vigour the *mule* is sexually sterile (*i.e.*, unable to reproduce) and have to be produced every time a new. The hybrid between the female ass and stallion (male horse over 3 years old) is called **hinny** which is also sterile.

9. Camels

Camels breed only during winter months (November to March).

Types of Camels. Camels are of two types.

(i) **Arabian Camels** (*Camelus dromedaris*). They have a single hump, short hair and are found in north Africa to India. They do not occur in wild state.

(ii) **Bactrian Camels** (*Camelus bactrianus*). They have two humps, long hair and found in Gobi desert of Central Asia. They also occur in wild form. Bactrian camels also occur in Ladakh (part of J & K, India).

Indian Breeds of Camels

(i) **Bikaneri.** They are found near Bikaner, Rajasthan and have good height, strong in-built and active habits.

(ii) **Jaisalmeri.** The animals are shorter and lighter than Bikaneri and found near Jaisalmer, Rajasthan.

(iii) **Mewari.** This breed is native of Mewar area of Rajasthan. The animals are stouter and little shorter than Bikaneri.

(iv) **Sindhi.** The camels of this breed are found in Rajasthan. Originally this breed is from Sindh.



Fig. 9.9. A. Arabian Camel. B. Bactrian Camel.

(v) **Kutchi.** This breed of camels is found in Kutch area of Gujarat.

Camel gets water regularly from the oxidation of fat present in the hump.

The common diseases of camels are Trypanosomiasis, (Surra), Anthrax, Camel pox. Pneumonia, Rabies and Jhooling.

III. Elephant

Elephant is the largest land animal which becomes sexually mature at the age of 8 to 16 years. It has a long gestation period of 22 months and lives upto hundred years. There are three species of elephants.

(i) **Indian Elephant** (*Elephas maximus*). It has small ears, high domed forehead and convex back, tusks are only in male but not always. It can be trained easily.

(ii) **African Elephant** (*Loxodonta africana*). It has large ears, convex sloping forehead. Tusks in both sexes. It is difficult to train.

(iii) **Pigmy (Pygmy) African Elephant** (*Elephas cyclotis*). It is much smaller than other two types of elephants.

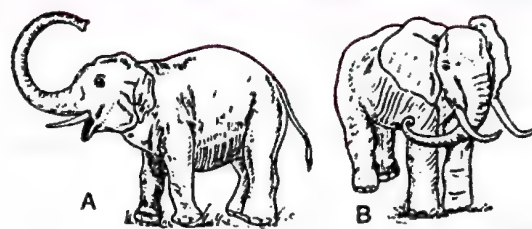


Fig. 9.10 . A. Indian Elephant.
B. African Elephant

11. Yak

Yak is found in Tibet, Ladakh, Garhwal, Kumaon, Sikkim, Lahaul and Spiti. The yak is highly adapted to cold climates of the Himalayas. It gives meat, hide and wool. The transport of people and goods in these regions would be impossible without this animal. The yak is also used for ploughing the land.

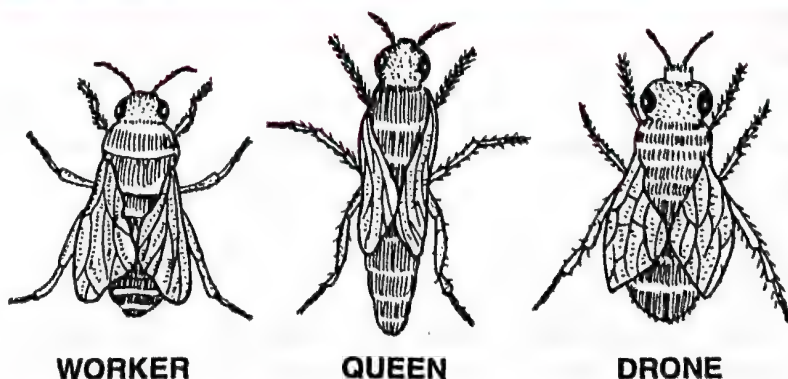


Fig. 9.11. Yak

BEE-KEEPING (APICULTURE)

Rearing of honey bees for obtaining honey and bee wax is called *apiculture*.

Castes of Honey bees. Honey bees build their nest combs on the trees. They are highly colonial, social and polymorphic insects. The honey bees have best developed social life. Three types of individuals (castes) are found in the colony of honey bees; (i) **Queen** is a fertile female which lays eggs. Normally one queen is found in one nest. (ii) **Drones** are males which mate with queen. Their number in the colony is not much. Drones are produced by parthenogenesis. (iii) **Workers** are sterile females and perform various duties of the colony. The queens and drones are fed by the workers. The worker bees are smallest members of the colony. They have chewing and lapping type of mouth parts, modified for collecting nectar and pollen of the flowers. The abdomen contains the wax glands and the sting.



WORKER

QUEEN

DRONE

Fig. 9.12. Castes of honey bee.

The worker bees are of three types (a) **Scavenger bees** (b) **Nurse bees** and (c) **Scout bees**.

Ernest Spytzner (1788) was the first to draw attention to the fact that bees communicate by means of definite movements now called "**bee dances**". **Prof Karl Von Frisch** decoded the language of "bee dances" and got "Nobel Prize" in medicine or physiology for it in 1973. He discovered that scout bees perform two types of dances for communication. (i) **Round dance** is performed when a newly discovered food source is close (less than 75 metres) to the hive (ii) **Tail wagging dance** is performed for long distance sources.

Eggs of queen hatch into white, legless **larvae** which spin delicate silken cocoons around themselves and turn into **pupae**. Each pupa develops into an adult. The adult comes out by cutting wall of cocoon first and secondly by breaking the wax cap of the cell.

During first 2 to 3 days, all larvae of bee are fed on a special proteinaceous food, called "**Royal jelly**" or **bee milk** which is secreted by the hypopharyngeal glands of the young workers. After that coarser food, the "**Bee Bread**", which is mixture of honey and pollen grain is given. However, the queen forming larvae are fed on royal jelly for the full larval life and these larvae are also taken for further development into a special chamber called the queen's chamber or cell.

Species of Honey bees. There are four important species of honey-bees ; (i) *Apis mellifera* (Italian Bee), (ii) *A. indica* (Indian Bee), (iii) *A. dorsata* (rock bee), (iv) *A. florea* (little bee). All of them occur in nature as wild insects. However, because of their high economic importance, the honey-bees, especially, *A. mellifera* are domesticated and cultured, viz., reared and bred in artificial hives. Of these the most common species in wild state is *Apis indica* while in domestic state it is *Apis mellifera*.

Importance of Honey bees. Honey bees have the following importance.

(i) **Honey.** The honey is a **neutral**, natural valuable tonic for human body. Honey is a sweet, viscous edible fluid. **Chemical composition of honey is** (i) **ash** 1.00%, (ii) **minerals** (0.22 to 0.3 per cent), e.g., calcium, iron, phosphate and manganese, (iii) **vitamins** (0.2 to 0.5 per cent), e.g., pantothenic acid, biotin, pyridoxin, choline, ascorbic acid, thiamine, riboflavin and niacin, (iv) **Sugars** (20 to 40 per cent), e.g., levulose (38.90%), dextrose (21.28%), maltose (8.81 %) and sucrose (1.9%), (v) **Water** (27.80%), (vi) **Amino acids, enzymes.** Honey also contains pollen.

The colour, flavour and smell of honey depend on the flowers from which nectar is collected. It is an energy rich food. One kilogram of honey contains 3200 calories. A number of Ayurvedic medicines are taken with honey.

(ii) **Bee wax.** Bee wax is made of secretion of worker bees' abdominal glands. It is a product of industrial importance. It is used in the manufacture of many items including cosmetics, shaving cream, face cream, ointments, plasters, carbon papers, pencils, electric goods, toothpaste, lotions, furniture-polishes, boot-polishes, protective coating, ink paints and candles. It is also used in model and mould making and in printing industry. It is also used in the laboratory for microtomy with the common wax for block preparation of the tissues.

(iii) **Pollination.** The honey bees are pollinators of many crop species such as sunflower, *Brassica*, apple and pear.

(iv) **Medicinal value.** A drug, prepared from the bodies of honey bees, is used in the treatment of **Diphtheria** and some other dangerous diseases. The **venom** of stings of honey bees has been used in the treatment of rheumatoid arthritis and snake bite.

Rearing of Honey bees. The honey-bees are reared in wooden boxes having a large

brood chamber placed on a wooden platform with an opening for the entry and the exit to the bees at the bottom. A number of frames coated with wax sheets having hexagonal imprints are placed in the chamber vertically with the help of wires. The bees start making cells along the margins of hexagonal imprints. Each wax sheet, known as **comb foundation**, provides the foundation for the bees to build combs on both the sides. A chamber called **super** having additional similar frames for more comb foundations meant for the expansion of the hive, is placed over the brood chamber. To start a colony in the artificial hive, a gravid (fertilized) queen is inducted into the brood chamber. Artificial hives are placed in gardens, orchards and fields having flowering plants to provide the pollen and nectar.

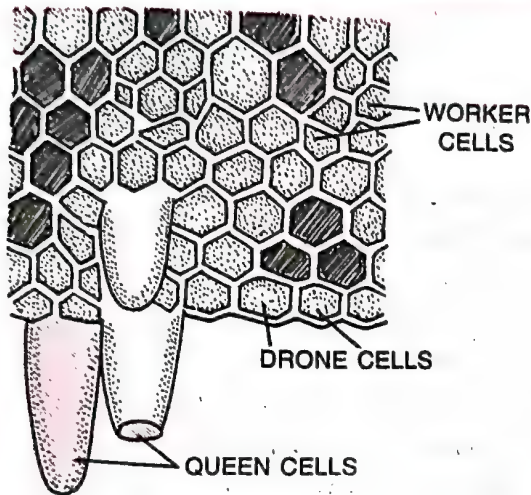


Fig. 9.13. A portion of the honey comb showing various types of cells.

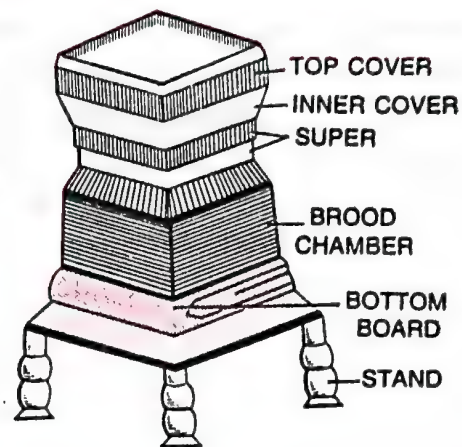


Fig. 9.14. Typical movable hive.

When sufficient honey has been stored, the combs are removed from the frames and then centrifuged to extract the honey. The same comb can be used again. The appliances used for the extraction of honey are a pair of gloves, a knife, a brush to remove the bees from taken out combs and a centrifuge.

How is nectar changed into honey ? Nectar is a sweet viscous secretion secreted by flowers of plants; by attracting the insects it helps in pollination. When the bee sucks the nectar from the flowers, it passes this nectar to its **honey sac** where it gets mixed with some acid secretion. In honey sac, sucrose (sugar) of the nectar is converted into dextrose and levulose by the action of invertase enzyme. After regurgitation the treated nectar finally changes into honey which is stored in special cells of hive for future use.

Bee Enemies. These include the wax moths (e.g., *Galleria mellonella*), wasp (e.g., *Vespa*), black ants (e.g., *Componotus compressus*) and bee eaters (e.g., *Merops orientalis* and king crow, *Dicrurus macrocerus*). Man is the last but worst enemy of honey bees.

Bee Diseases. Honey bees suffer from **Nosema** disease caused by a protozoan *Nosema apis*, and **acarine disease** caused by a parasitic mite, *Acarapis woodi*.

FISHERIES

Fish are aquatic, cold blooded and craniate vertebrates belonging to the super class Pisces under phylum Chordata. Fishery is a kind of industry which is concerned with the catching, processing or selling of fish, shellfish (molluscs, each has a shell in two halves, used for food, e.g., mussels, oysters, etc.) and crustaceans.

Economic Importance of Fish

(i) **Fish as food.** The fish flesh is an excellent source of protein, has very little fat, carries a good amount of minerals and vitamins A and D and rich in iodine. Above all man can digest it easily. Some important edible fish of India are given in the Table 9.6 & 9.7.

(ii) **Fish for controlling diseases.** Diseases like malaria, yellow fever and other dreadful diseases that are spread through mosquitoes can be controlled. **Larvivorous fish** eat larva of mosquito. The important larvivorous fish are *Gambusia*, *Panchax*, *Haplochitus*, *Trichogaster*, etc.

(iii) **Scientific value.** Some fish like the lung fish are of zoological importance because of their discontinuous distribution and anatomical features.

(iv) **Aesthetic value.** A large number of fish are cultured in aquarium for their beauty and graceful movements. The important aquarium fish are *Macropodus*, *Trichogaster*, *Carassinus* (gold fish) and *Pterophyllum* (angel fish).

(v) **Fishery Bye-products.** (a) **Fish oil.** It is extracted from the liver of the sharks, sawfishes, skates and rays and has medicinal value. These mainly include cod liver oil and shark liver oil. (b) **Fish Manure.** The fish waste after the extraction of oil, is used as fertilizers. (c) **Fish Glue.** It is a sticky product, obtained from the skin of the cod and is used as gum. (d) **Isinglass.** It is a gelatinous substance, obtained from the air bladder of perches, Indian Salmons and cat fish used in the preparation of special cement and in the clarification of wine and beer. (e) **Shagreen.** The skin of sharks and rays, which has pointed and sharp placoid scales are used in polishing the wood and other materials. It is also used for covering the jewellery boxes and swords. (f) **Leather.** A highly durable type of leather is prepared from the skin of sharks and rays. (g) **Artificial pearls.** The silvery boney scales of cyprinids (a type of fish) are used in the manufacture of artificial pearls especially in France.

(vi) **Employment.** Development of fishing industry generates more employment opportunities.

(vii) **Source of Income.** The fishing industry has brought a lot of income to the farmers in particular and the country in general. Now we can talk about "**Blue Revolution**" (fish production) on the same lines as 'Green Revolution' (for producing enough food for all).

Differences Between Aquaculture and Pisciculture

Aquaculture	Pisciculture
1. It involves production of all types of aquatic organisms in water bodies.	1. Production of fishes is called pisciculture.
2. There is small quantity of special feed from outside.	2. Here fish feed is provided from outside.
3. Important economically substances are obtained.	3. It gives only food substances.

Types of Fisheries. There are two main types of fisheries : Inland fisheries and marine fisheries.

Inland or Fresh Water Fisheries. Inland fishery deals with the fishery aspects of waters other than marine water. Potentially, the vast and varied inland fishery resources of India are one of the richest in the world. They pertain to two types of waters, namely, the fresh and the brackish. The former includes the country's great river systems, an extensive

network of irrigation canals, reservoirs, lakes, tanks, ponds, etc. The estuaries, lagoons and mangrove swamps constitute the brackish type of water. In pisciculture (culture fisheries), which generally pertains to small water bodies, the fish seed has to be sown, tended, nursed, reared and finally harvested when grown to table size. In the case of capture fisheries, which pertain to the rivers, estuaries, large reservoirs, as well as big lakes, man has only to reap without having to sow. Some important edible fresh waterfishes of India are given in the table 9.6.

Table 9.6. Important Edible Fresh Water Fishes of India

Name	Name
1. Rohu (<i>Labeo rohita</i>)	5. Mangur (<i>Clarias batrachus</i>)
2. Calbasu (<i>L. calbasu</i>)	6. Singhi (<i>Heteropneustes fossilis</i>)
3. Catla (<i>Catla catla</i>)	7. Malli (<i>Wallago attu</i>)
4. Singhara (<i>Mystus seenghala</i>)	8. Mirgala (<i>Cirrhinus mrigala</i>)

Types of Breeding. According to the mode of breeding there are two categories, natural breeding and induced breeding.

(i) **Natural Breeding** (Bundh breeding). The natural bundhs are special types of ponds where natural water resource conditions are managed for the breeding of culturable fish. These bundhs are constructed in large low-lying areas to accumulate large quantity of rain water. These bundhs are having an outlet for the exit of excess rain water.

(ii) **Induced Breeding.** In artificial method of fertilization ova from the females and the sperms from the males are taken out by artificial mechanical process and the eggs are got fertilized by the sperms. Different methods are used for induced breeding. Here induced breeding by hormones method is briefly described. The gonadotropin hormone (FSH and LH) secreted by pituitary gland influences the maturation of gonads and spawning in fishes. In India, Khan (1938) successfully induced *Cirrhinus mrigala* to spawn by injecting mammalian pituitary hormone.

(iii) **Composite Fish Farming.** It is found that if few selected species of fish are stocked together in proper proportion in a pond, total production of fish is increased many times. This mixed farming is called composite farming. It has some advantage-compatible species do not harm each other, all available areas are fully utilised, no competition among different species is found and fish may have beneficial effect on each other. *Catla catla*, *Labeo-rohita* and *Cirrhina mrigala* are surface feeder, column feeder and bottom feeder respectively and are used for composite farming.

Marine Fisheries. Marine fishery deals with the fishery aspects of the sea water or ocean.

Table 9.7. Important Edible Marine Fish of India

Name	Name
1. Bombay duck (<i>Harpodon sp</i>)	7. Mackerel (<i>Rastrelliger</i>)
2. Eel (<i>Anguilla sp</i>)	8. Flying Fish (<i>Exocoetus</i>)
3. Hilsa (<i>Hilsa</i>)	9. Ribbon Fish (<i>Trichiurus</i>)
4. Pomfret (<i>Stromateus</i>)	10. Tuna (<i>Thunnus</i>)
5. Salmon (<i>Aluitheronema</i>)	11. Seer Fish (<i>Scomberomorus</i>)
6. Sardine (<i>Sardinella</i>)	

Hilsa migrates from the sea to the river for breeding. Dr. Hora studied the migration of Hilsa.

Fish Diseases Caused by Parasites and Pathogens

1. **Bacterial Diseases.** Two bacterial diseases are very important.
 - (i) *Abdominal dropsy of Carps* is caused by *Aeromonas punctuata*.
 - (ii) *Furunculosis of Salmon* and trouts is caused by *Aeromonas salmonicida*.
2. **Viral Diseases.** Economically most important is the *viral haemorrhage septicaemia* (VHS) of rainbow trouts.
3. **Protozoan Diseases.** Main protozoan diseases are caused by *Costia*, *Myxobolus* and *Trypanosoma*.
4. **Fungal Diseases.** The *gill rot (branchyomyces)* of carps involves the attack of *Saprolegnia* on the gills of carps.
5. **Worm Diseases.** Worms of four groups are parasites on fish. The flatworms (trematodes), tapeworms (cestodes), round worms (nematodes) and thorny-headed worms (acanthocephalans).
6. **Common Ectoparasites.** Two ectoparasites of fish are most important, the **fish lice** (*Argulus*, *Lernaea* and *Ergasilus*) and the **fish leech** (*Piscicola*). Both parasites weaken fish by feeding on its blood.

PLANT BREEDING

Green Revolution. Traditional farming can only yield limited food for humans and animals. Better management can increase yield but only to a limited extent. But plant breeding as a technology increased yield to a very large extent. In India, "**Green Revolution**" was responsible for our country to not only meet our requirements in food production but also helped us to export it. **Monkambu Sambasivan Swaminathan** (M.S. Swaminathan) initiated collaboration with **Dr. Borlaug** which reached the highest point into the "Green Revolution" through introduction of Mexican varieties of wheat in India. Green Revolution depended mainly on plant breeding techniques for high yielding and disease resistant varieties in wheat, rice, maize, etc.

1. What is Plant Breeding ?

Plant breeding is the genetic improvement of the crop in order to create desired plant types that are better suited for cultivation, give better yields and are disease resistant. Conventional plant breeding is in practice from 9,000–11,000 years ago. Most of our major food crops are derived from the domesticated varieties. But now due to advancements in genetics, molecular biology and tissue culture, plant breeding is being carried out by using molecular genetic tools. Classical plant breeding includes hybridization (crossing) of pure lines, artificial selection to produce plants with desirable characters of higher yield, nutrition and resistance to diseases.

When the breeders wish to incorporate desired characters (traits) into the crop plants, they should increase yield and improve the quality. Increased tolerance to salinity, extreme temperatures, drought, resistance to viruses, fungi, bacteria and increased tolerance to insect pests should also be the desired traits in these crop plants.

Various Steps Required For Developing New Varieties

The various steps required for developing new varieties are as follows :

(i) **Collection of Variability (Collection of Germplasm).** Germplasm is the sum total of all the alleles of the genes present in a crop and its related species. The germplasm of any crop species consists of the following types of materials: (i) cultivated improved varieties, (ii) improved varieties that are no more in cultivation, (iii) old local or 'desi' varieties, (iv) pure lines produced by plant breeders, and (v) wild species related to the crop species.

The entire collection (of plants/seeds) having all the diverse alleles for all genes in a given crop is called **germplasm collection**. A good germplasm collection is essential for a successful breeding programme.

(ii) **Evaluation and Selection of Parents.** The germplasm is evaluated to identify plants with desirable combination of characters. Selection of parents is picking up seeds of only those plants for multiplication which have the desired traits. For example, grain length in rice is variable— longer grains, intermediate grains and shorter grains. If we select the seeds of the longest grains and sow them to grow the next generation, the selected population of rice plants will have on an average, longer grains than the original population.

(iii) **Cross-Hybridization among Selected Parents.** **Hybridisation** is the most common method of creating genetic variation. Hybridisation is crossing of two or more types of plants for bringing their traits together in the progeny. It brings about useful genetic/ heritable variations of two or more lines together. **Line** is a group of individuals related to descent and have similar genotype. The individuals or lines used in hybridisation are called **parents**. Hybridisation takes a lot of time. As stated earlier a wheat variety HUW 468 took 12 years to develop. Hybridisation may involve a **single cross** (two plants) or **multiple cross** (more than two plants). Wheat variety C-306 was developed through multiple cross between C-591 (Reagent 1974 \times Ch₂-3) and hybrid of P-19 \times C-281. Hybridisation may further be (i) **intravarietal**, (ii) **intervarietal** (= **intraspecific**) or (iii) **interspecific** and (iv) **intergeneric**. Intervarietal hybridisation is the process of crossing individuals of different lines or varieties of the same species to produce hybrid, e.g., different varieties of wheat are mated. Interspecific hybridisation is the process of crossing individuals of two different species to produce a hybrid. Examples of interspecific hybridisation are the development of rice variety ADT-37 from a cross between *Oryza japonica* and *O. indica* and all the sugarcane varieties being cultivated today. In intergeneric hybridisation, the cross is between two different genera.

The **procedure of hybridisation** involves the following steps.

(a) **Selection of Parents with Desired Characters.** All the desirable traits which are required in the new crop variety are first selected.

(b) **Selfing.** The selected plants as parents are allowed to undergo self breeding to bring about homozygosity of the desired traits.

(c) **Emasculation.** The removal of anthers (male parts) from a bisexual flower, before the anthers mature is called **emasculation**. This prevents self-pollination in these flowers.

(d) **Bagging.** The emasculated flowers are immediately covered by paper, plastic or polythene bags. The process is called **bagging**. It prevents unwanted pollen to come in contact with emasculated flowers. This prevents contamination from foreign pollen grains.

(e) **Tagging.** The emasculated and bagged flowers must be tagged by writing every step with date and time. The bagging and pollination is incomplete without tagging.

(f) **Artificial Pollination (= Crossing).** Pollen grains are collected from the covered flowers of the 'male' parents in clean sterile paper/polythene bags or test tubes. The collected pollen grains can be stored for later use. When the stigma of the emasculated flower of 'female' parent matures, the covering bag is removed for a short while. The stigma is dusted with pollen grains by means of a clean brush. Controlled pollination by bringing selected pollen grains in contact with a stigma through human efforts is called **artificial pollination**. After pollination, the emasculated flower is covered again till the stigma remains receptive. Bags are discarded when fruits begin to develop. The seeds produced by these flowers of the female parent are the **hybrid** or **F₁ Seeds**. These seeds are stored for testing. These seeds are sown in the next season. There will be segregation, independent assortment and recombination in the F₂ and later generations are obtained from these F₁ seeds.

(iv) **Selection and Testing of Superior Recombinants.** This step comprises selecting, among the progeny of the hybrids, those plants that have the desired character combination. The selection process yields plants that are superior to both of the parents. These plants are self-pollinated for several generations till they come to a state of uniformity (homozygosity) so that the characters will not separate in the progeny. **Selection** is of two types— self-pollinated and cross pollinated.

(a) **Selection in Self-pollinated Crops.** The degree of cross pollination is less than 5%. There is repeated self pollination of selected plants till superior homozygous genotypes are obtained. The best one is used as new variety. The self-pollinated progeny of homozygous plant constitutes a **pure line**. All the plants in pure line have identical genotype. The wheat variety HUW 468 is a good example of pure line. Variation appearing later in such a pure line is due to environment.

(b) **Selection in Cross-pollinated Crops.** The cross-pollinated crops are heterozygous for most of their genes and their population contains plants of several different genotypes. Some of these genotypes are superior but many are inferior. Superior genotype plants are selected and are allowed to crossbreed (these plants are not allowed to self breed) so that heterozygosity is also maintained. Selection can be continued in a few successive generations of cross-pollinated crops.

Differences Between Pureline Selection and Mass Selection

<i>Pureline Selection</i>	<i>Mass Selection</i>
1. Used in self-pollinated species.	1. Used in both cross and self pollinated species.
2. Genetic variation is absent.	2. Genetic variation is present.
3. Pureline variety has narrow adaptation.	3. Mass selected variety has wide adaptation.
4. Produce of variety is highly uniform.	4. Produce of variety is less uniform.

(v) **Testing, Release and Commercialisation of New Cultivars.** The newly selected lines are evaluated for their yield and other agronomic traits of quality, disease resistance, etc. This evaluation is done by growing these in the research field and recording their performance under ideal fertiliser (application), irrigation, etc. After the evaluation in the research fields, the testing of the materials is done in the farmer's fields, for at least three growing seasons at different locations in the country, representing all the agroclimatic zones. The material is evaluated in comparison to the best available crop cultivar. Thus the seeds of new variety are multiplied and made available to the farmers.

Examples of some improved varieties

- (1) **Wheat**— Kalyan Sona, Sonalika.
- (2) **Rice**— Jaya and Ratna
- (3) **Sugarcane**— *Saccharum barberi*, *Saccharum officinarum*
- (4) **Rapeseed mustard Brassica**— *Pusa swarnim*

High Yielding Varieties (HYVs)

India is an agricultural country. Agriculture contributes about 33 per cent of India's GDP and gives employment to about 62 per cent of the population. After India's independence, one of the main challenges faced by the country was enough food production for the increasing population. The development of several high yielding varieties of wheat and rice in 1960 increased yields per unit area. This phase is often called the **Green Revolution**. Some **high yielding varieties (HYVs)** of Indian hybrid crops are given in the figure 9.15.

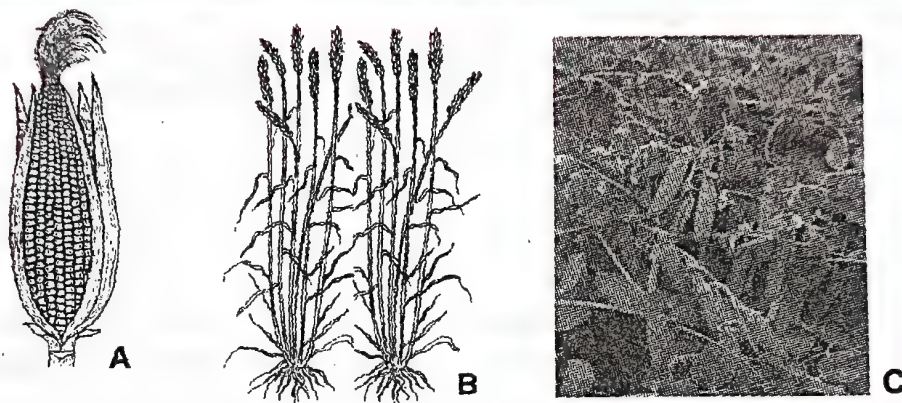


Fig. 9.15. Some Indian hybrid crops. A, Maize. B, Wheat. C, Garden peas.

(i) **Wheat.** In 1960 to 2000 wheat production increased from 11 million tonnes to 75 million tonnes while rice production increased from 35 million tonnes to 89.5 million tonnes. It was due to the development of semi-dwarf varieties of wheat and rice. Nobel Prize winner Norman E. Borlaug of International Centre for Wheat and Maize Improvement in Mexico developed semi-dwarf wheat. In 1963, many lines like *Sonalika* and *Kalyan Sona* were selected from these that were high yielding and disease resistant. They were introduced all over the wheat growing areas of India. Some more improved varieties of wheat are (i) Lerma Roja 64-A, (ii) Sonora 64-Early, (iii) Safed Lerma, (iv) Chhoti Lerma, (v) Sharbati Sonora.

(ii) **Rice.** Semi-dwarf rice varieties were developed from IR-8 at International Rice Research Institute (IRRI), Philippines and Taichung Native-1 from Taiwan. The developed varieties were introduced in 1966. Later on better yielding semi dwarf varieties *Jaya* and *Ratna* were developed in India. As stated earlier M.S. Swaminathan contributed much for Green Revolution in India.

(iii) **Sugarcane.** *Saccharum barberi* was originally grown in North India, but had poor sugar content and yield. However, *Saccharum officinarum* had higher sugar content and thicker stems but did not grow well in North India. These two species were crossed to have sugarcane varieties combining the desirable qualities of high sugar, high yield, thick stems and ability to grow in the sugarcane belt of North India.

(iv) **Millets.** Plants producing a large crop of small seeds are called **millets**. Hybrid

bajara, jowar and maize have been developed in India. From hybrid varieties, the development of several high yielding varieties resistant to water stress have been possible.

2. Plant Breeding for Disease Resistance

Fungal, bacterial, viral and nematode pathogens attack the cultivated crops. Crop losses can be upto 20-30 per cent. In such situation if the crops are made disease resistant, food production is increased and use of fungicides and bactericides would also be reduced. Before breeding, it is important to know the causative organism and the mode of transmission. Some fungal diseases are rusts, e.g., brown rust of wheat, red rot of sugarcane and late blight of potato; by bacteria—black rot of crucifers and some viral diseases are tobacco mosaic, turnip mosaic, etc.

Disease is an abnormal unhealthy condition produced in an individual due to defective nutrition, defective heredity, unfavourable environment or infection. Disease causing organism is called **pathogen**. The individual in which a disease is caused by a pathogen is called **host**. The development of disease in a plant depends on three factors : (i) host genotype, (ii) pathogen genotype and (iii) the environment as shown in the figure 9.16.

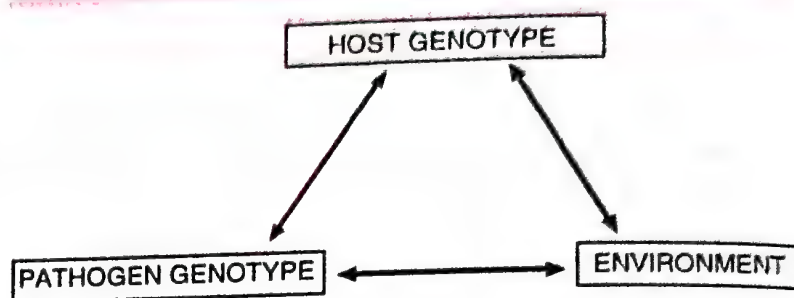


Fig. 9.16. Three factors responsible for development of a disease.

Some host genotypes possess the ability to prevent a pathogen strain from producing disease. Such host lines are called **resistant**, and this ability is called **resistance** or **disease resistance**. The term **strain** has a similar meaning for the pathogen as line has for the host. Those lines of a host that are not resistant to the pathogen are called **susceptible**. A successful breeding for disease resistance depends mainly on the following two factors: (i) a good source of resistance, and (ii) a dependable disease test. In **disease test**, all the plants are grown under conditions in which a susceptible plant is expected to develop disease. Therefore, disease resistant crop plants should be produced to avoid infection.

Quarantine. *Argemone mexicana* is an example of a weed that entered India with an introduction. Therefore, all introductions are carefully examined for the presence of weeds, insects and disease-causing organisms; this is known as **quarantine**.

Inbreeding Depression. Loss of vigour and appearance of a number of defective traits associated with inbreeding, is called **inbreeding depression**.

Heterosis (= Hybrid Vigour). Heterosis is the reverse of inbreeding depression. **Heterosis** or **hybrid vigour** is the phenotypic superiority of the hybrid over either of its parents in one or more traits. Mules produced by the cross of mares (female horses) and donkeys (males) have greater strength and resistance to disease and larger life span than either parents.

Methods of Breeding for Disease Resistance

Breeding is carried out either by conventional breeding techniques described earlier or by mutation breeding. The conventional method of breeding for disease resistance is hybridization and selection. The various sequential steps are : screening germplasm for resistance sources, hybridization of selected parents, selection and evaluation of hybrids and testing and

release of new varieties. Some of the released crop varieties bred by hybridization and selection for disease resistance to fungal, bacterial and viral diseases are given below :

Table 9.8 : Some released crop varieties bred by hybridization and selection, for disease resistance to fungi, bacteria and viral diseases.

Crop	Variety	Resistance to diseases
Wheat	Himgiri	Leaf and stripe rust, hill bunt
Brassica	Pusa swarnim	White rust
Cauliflower	Pusa shubhra, Pusa Snowball K-1	Black rot and Curl blight black rot
Cowpea	Pusa Komal	Bacterial blight
Chilli	Pusa Sadabahar	Chilly mosaic virus, Tobacco mosaic virus and Leaf curl

Conventional breeding is often constrained by the availability of limited number of disease resistance genes that are present and identified in various crop varieties. Inducing mutations in plants sometimes leads to desirable genes being identified. Plants having these desirable characters can either be multiplied directly or can be used in breeding. Other breeding methods that are used are mutation, selection among somaclonal variants and genetic engineering.

Polyploidy in Crop Improvement (Polyploid Breeding)

An organism which has more than two sets of chromosomes or genomes per cell is called **polyploid** and this condition is known as **polyploidy**. Most important crops having polyploidy condition are wheat, bananas, cotton, potatoes, sugarcane and tobacco. Polyploidy occurs in nature due to the failure of chromosomes to separate at the time of anaphase either due to nondisjunction or due to nonformation of spindle. It can be artificially induced by application of colchicine. Depending upon the number of genomes present in a polyploid, it is known as triploid ($3n$), tetraploid ($4n$), pentaploid ($5n$), hexaploid ($6n$), etc. Polyploids with odd number of genomes (*i.e.*, triploids, pentaploids) are sexually sterile because the odd chromosomes do not form synapsis. They are, therefore, propagated vegetatively, *e.g.*, Banana, Pineapple. Polyploids also do not cross-breed freely with diploids.

Polyploidy is of two types— autopolyploidy and allopolyploidy.

(i) **Autopolyploidy**. It is a type of polyploidy in which there is a numerical increase of the same genome, *e.g.*, autotriploid (AAA), autotetraploid (AAAA). Some of the crop and garden plants are autopolyploids, *e.g.*, Maize, Rice, Gram. Autopolyploidy induces *gigas* effect.

(ii) **Allopolyploidy**. It has developed through hybridisation between two species followed by doubling of chromosomes (*e.g.*, AABB). Allotetraploid is the common type. Allopolyploids function as new species, *e.g.*, Wheat, American Cotton, *Nicotiana tabacum*. Two recently produced allopolyploids are *Raphanobrassica* and *Triticale*. Thus

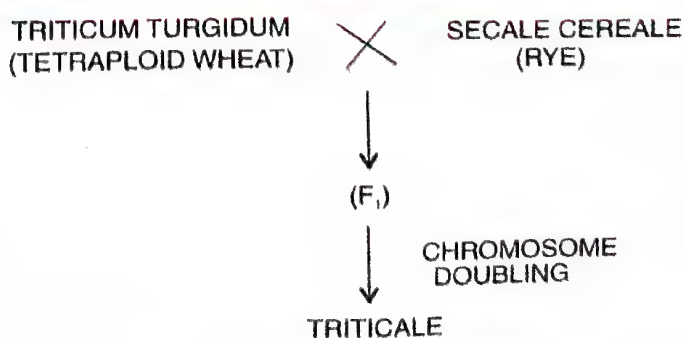


Fig. 9.17. Production of triticale from *Triticum turgidum* (tetraploid wheat) and *Secale cereale* (rye)

Triticale is a hybrid of wheat (*Triticum turgidum*) and rye (*Secale cereale*). Among artificially produced allopolyploidy, *Triticale* is the first man made crop derived by crossing wheat and rye.

Autoallopolyploidy is a type of allopolyploidy in which one genome is in more than diploid state. Commonly autoallopolyploids are hexaploids (AAAABB), e.g., *Helianthus tuberosus*.

Mutation Breeding. Mutation is a sudden and heritable change in a character of an organism. Mutation can be due to a change in any one of the following: (a) base sequence of the concerned gene, (b) chromosome structure and chromosome number.

Spontaneous Mutations. Mutations occurring naturally are called spontaneous mutations. They are both germinal and somatic. Useful somatic mutations can be incorporated in crop improvement only in vegetatively propagated plants, e.g., seedless grape, naval orange, Bhaskara banana. Vegetative propagation is also useful in maintaining germinal variation got through sexual reproduction, e.g., apple, mango, potato, sugarcane. Thus spontaneous mutations are the source of all the genetic variations occurring in all living things today.

Mutagens and Induced Mutations. Rate of spontaneous mutations is very low. Therefore, rate of mutation is increased by means of certain agents called **mutagens**. Mutagens are of two types (a) chemical and (b) physical mutagens. **Chemical mutagens** are some chemicals such as ethylmethane sulphonate (EMS) and sodium azide, that induce mutations. **Physical mutagens** are different kinds of radiation like X-rays, gamma-rays, ultraviolet rays, etc., that cause mutations. These mutagens induce changes in DNA and chromosomes, which produce mutations. Mutations produced in response to mutagens are known as **induced mutations**. They were first produced by Muller (1927) with the help of X-rays on *Drosophila* and by Stadler in maize. Use of induced mutations in plant breeding to develop improved varieties is called **mutation breeding**.

In India, over 200 varieties have been developed through mutation breeding.

Selection amongst Somaclonal Variation. Genetic variation present among plant cells during tissue culture is called **somaclonal variation**. The term somaclonal variation is also used for the genetic variation present in plants regenerated from a single culture. This variation has been used to develop several useful varieties. Some of the somaclonal variations are stable and useful, e.g., resistance to diseases and pests, stress tolerance, male sterility, early maturation, better yield, better quality, etc. Thus somaclonal variations have produced wheat tolerant to rust and high temperature, Rice to leaf ripper and Tungro virus, Potato to *Phytophthora infestans* (late blight of Potato), etc. Other useful variations include high protein content of Potato, short duration Sugarcane and increase shelf life of Tomato.

Difference Between Somaclones and Clones

<i>Somaclones</i>	<i>Clones</i>
These are genetically identical plants developed from any part of a plant by tissue culture/micropropagation.	All the progenies of a single plant obtained by a sexual reproduction is called clone.

Genetic Engineering (Recombinant DNA Technology). This is a process in which the alteration of the genetic make up of cells is done by deliberate and artificial means. This process involves transfer or replacement of genes to create recombinant DNA.

This is done by cutting DNA molecules at specific sites to get fragments containing desirable and useful genes from one type of cell. Thereafter, these genes can be inserted into

a suitable carrier or vector. Now, these recombinant DNA can be put into completely different cell of a bacterium or plant or animal cell. By this method, they acquire useful characters, such as disease resistance or to make useful enzymes, hormones, vaccines, etc.

This process involves manipulation or engineering of the DNA (genes), therefore, the term '**genetic engineering**' has been used. The recombinant DNA molecules can be cloned and amplified to an unlimited extent.

Genetic Engineering or Recombinant DNA Technology has been described in details in the chapters 11 and 12.

3. Plant Breeding for Developing Resistance to Insect Pests

Insects and pests infestation are the two major causes for large destruction of crop plant and crop. Insect resistance in host crop plants is due to morphological, biochemical or physiological characters. Hairy leaves of many plants are associated with resistance to insect pests. For example, resistance to jassids in cotton and cereal leaf beetle in wheat. Solid stems in wheat lead to non-preference by the stem saw fly and smooth leaved and nectarless cotton varieties do not attract bollworms. Low nitrogen, sugar and high aspartic acid in maize develops resistance to maize stem borers.

Table 9.9 : Some released crop varieties bred by hybridization and selection, for insect pest resistance.

Crop	Variety	Resistance to diseases
Brassica (rapeseed mustard)	<i>Pusa Gaurav</i>	Aphids
Flat bean	<i>Pusa Sem 2,</i> <i>Pusa Sem 3</i>	Jassids, aphids and fruit borer
Okra (Bhindi)	<i>Pusa Sawani</i> <i>Pusa A-4</i>	Shoot and fruit borer

Breeding methods for insect pests resistance include the same steps as for any other agronomic character like yield or quality as described above. Sources of resistance genes may be cultivated varieties, germplasm collections of the crop or wild relatives of the crop.

4. Plant Breeding for Improved Food Quality

It is estimated that more than 840 million people in the world do not have adequate food to meet their daily requirements. Three billion people suffer from protein, vitamins and micronutrient deficiencies or 'hidden hunger' because these people cannot afford to buy adequate vegetables, fruits, legumes, fish and meat. Their food does not contain essential micronutrients specially iron, iodine, zinc and vitamin A. This increases the risk for disease, reduces mental abilities and life span. Breeding of crops with higher levels of vitamins and minerals or higher protein and healthier fats is called **biofortification**. This is the most practical aspect to improve the health of the people.

Plant breeding is undertaken for improved nutritional quality of the plants. Following are the objectives of improving :

- | | | |
|---------------------------------|---|----------------------------------------|
| (1) Protein content and quality | ; | (2) Oil content and quality |
| (3) Vitamin content and | ; | (4) Micronutrient and mineral content. |

Maize hybrids that had twice the amount of the amino acids— lysine and tryptophan, compared to existing maize hybrids were developed in 2000. Wheat variety with high protein content *Atlas 66* has been used as a donor for improving cultivated wheat. It was possible

to develop an iron rich variety containing more than five times as much iron as in usually consumed varieties.

There are eight essential amino acids. When these amino acids are present in the protein of our diet in sufficient amount, they constitute **protein quality**. Proteins of cereals and millets are deficient in two amino acids, *i.e.*, lysine and tryptophan. Whereas pulses are deficient in methionine and cysteine — both are sulphur containing amino acids.

Indian Agricultural Research Institute (IARI), New Delhi, has also developed many vegetable crops that are rich in minerals and vitamins. For example, vitamin A enriched carrots, pumpkin, spinach, vitamin C enriched bitter gourd, *Bathua*, tomato, mustard, calcium and iron enriched spinach and *bathua*; and protein enriched beans (broad lablab, French and garden peas).

SINGLE CELL PROTEIN (SCP)

As we know that demand of food is increasing due to increase in human and animal population, the shift from grain to meat diets does not solve the problem as it takes 3–10 kg of grain to produce 1 kg of meat by animal farming. More than 25 per cent of human population is suffering from hunger and malnutrition. One of the alternate sources of proteins for animal and human nutrition is single cell protein (SCP). Microorganisms are used for the preparation of fermented foods (*e.g.*, cheese, butter, *idlis*, etc.). Some microorganisms (*e.g.*, blue green algae— *Spirulina* and mushrooms— fungi) are being used as human food. Now efforts are being made to produce microbial biomass using low cost substrates. Microbes like *Spirulina* can be grown on waste water from potato processing plants (containing starch), straw, molasses, animal manure and even sewage, to produce food rich in proteins, minerals, fat, carbohydrates and vitamins. This biomass is used as food by humans. The cells from microorganisms such as bacteria, yeasts, filamentous algae, treated in various ways and used as food, are called **single cell protein (SCP)**. The term SCP does not indicate its actual meaning because the *biomass is not only obtained from unicellular microorganisms but also from multicellular microorganisms*.

Thus SCP is produced using bacteria, algae, fungi (yeasts, etc). The substrates used for SCP production range from CO₂ (used by algae) through industry effluents like whey (water of curd), etc. to low-cost organic materials like saw dust and paddy straw. Commercial production of SCP is mostly based on yeasts and some other fungi, *e.g.*, *Fusarium graminearum*. In most cases, SCP has to be processed to remove the excess of nucleic acids. SCP is rich in high quality protein and is poor in fats. Both high quality of protein and low quantity of fats constitute good human food.

It has been estimated that a 250 kg cow produces 200 g of protein per day. In the same period 250 g of a microorganism like *Methylophilus methylotrophus* because of its high content of biomass production and growth, can produce about 25 tonnes of protein.

Some Common Microbes as SCP producers

- (i) **Cyanobacteria** – *Spirulina*
- (ii) **Bacteria** – *Methylophilus methylotrophus*
- (iii) **Yeasts** – *Candida utilis*
- (iv) **Filamentous fungi** – *Fusarium graminearum*

Advantages of SCP (i) It is rich in high quality protein and poor in fat content. (ii) It reduces the pressure on agricultural production systems for the supply of the required

proteins. (iii) SCP production is based on industrial effluents so it helps to minimise environmental pollution. (iv) SCP can be produced in laboratories throughout the year.

Role of Plant Breeding

Plant breeding has played an important role in enhancing food production :

- (i) *Triticale* is a man-made allopolyploid developed from *Triticum turgidum* and *Secale cereale*.
- (ii) Lysine-rich maize varieties like Shakti, Rattan and Protina have been developed.
- (iii) Through mutation breeding, more than 200 varieties of crops have been developed.
- (iv) Disease resistance in plants has been introduced through breeding.
- (v) All the sugarcane varieties that are cultivated today are interspecific hybrids.
- (vi) Plant breeding has also given us improved varieties of crops like Sonora-64 of wheat and Taichung Native -1 of rice.

PLANT TISSUE CULTURE

Meaning of Plant Tissue Culture

Plant tissue culture is the technique of maintaining and growing plant cells, tissues or organs especially on artificial medium in suitable containers under controlled environmental conditions. The part which is cultured is called **explant**, i.e., any part of a plant taken out and grown in a test tube, under sterile conditions in special nutrient media. This capacity to generate a whole plant from any cell/explant is called **cellular totipotency**. In fact, the whole plant can be regenerated from any plant part (referred to as explant) or cells. **Gottlieb Haberlandt** first initiated tissue culture technique in 1902. Haberlandt is considered 'Father of Plant Tissue culture'.

Hormones used in Plant Tissue Culture

1. **Auxins** neoline (Indole-3-acetic acid, Indole-3-butyric acid, Potassium Salt— Naphthalene acetic acid 2, 4-Dichlorophenoxyacetic acid p-Chloro-phenoxy acetic acid)
2. **Cytokinins** (6-Benzylaminopurine, 6-Dimethylallylaminopurine (2ip), Kinetin)
3. **Gibberellins** (Gibberellic Acid)
4. **Abscisic Acid** (ABA) (Absciscic Acid)
5. **Polyamines** (Putrescine, Spermidine)

Environmental Conditions

There are three important aspects *in vitro* (outside the living organism and in an artificial environment) culture namely (i) **nutrient medium**, (ii) **aseptic conditions** and (iii) **aeration of the tissue**

1. Nutrient Medium

The composition of plant tissue culture medium can vary depending upon the type of plant tissues or cell that are used for culture.

A typical (generalized) nutrient consists of inorganic salts (both micro and macro elements), a carbon source (usually sucrose), vitamins (e.g., nicotonic acid, thiamine, pyridoxine and myo-inositol), amino acids (e.g., *arginine*) and growth regulators (e.g., auxins like 2,4-D or 2,4-dichlorophenoxyacetic acid and cytokinins such as BAP = benzylaminopurine and gibberellins). Other compounds like casein hydrolysate, coconut milk, malt extract, yeast extract, tomato juice, etc. may be added for specific purposes. Plant hormones play impor-

tant role in growth and differentiation of cultured cells and tissues. An optimum *pH* (usually 5.7) is also very important. The most extensively used nutrient medium is MS medium which was developed by Murashige and Skoog in 1962. Usually a gelling agent agar (a polysaccharide obtained from a red algae *Gelidium amansi*) is added to the liquid medium for its solidification.

2. Aseptic Conditions (Sterilization)

Nutrient medium contains ample sugar which increases growth of microorganisms such as bacteria and fungi. These microbes compete with growing tissue and finally kill it. It is essential to maintain aseptic conditions of tissue culture. Thus sterilization means complete destruction or killing of microorganisms so that complete aseptic conditions are created for *in vitro** culturing.

3. Aeration of the Tissue

Proper aeration of the cultured tissue is also an important aspect of culture technique. It is achieved by occasionally stirring the medium by stirring or by automatic shaker.

Plant Material—The Explant

Any part of a plant taken out and grown in test tube under sterile conditions in special nutrient media is called explant.

Methods of Plant Tissue Culture

Plant tissue culture includes two major methods :

(A) Type of *in vitro* growth—callus and suspension cultures.

(B) Type of explant— single cell culture, shoot and root cultures, somatic embryo culture, meristem culture, anther culture and haploid production, protoplast culture and somatic hybridisation, embryo culture, ovule culture, ovary culture, etc.

Callus and Suspension Cultures

In callus culture, cell division in explant forms a callus. **Callus** is irregular unorganised and undifferentiated mass of actively dividing cells. Darkness and solid medium gelled by agar stimulates callus formation. The medium ordinarily contains the auxin, 2,4-D, (2, 4-dichlorophenoxy acetic acid) and often a cytokinin like BAP (Benzyl aminopurine). Both are growth regulators. This stimulates cell division in explant. Callus is obtained within 2–3 weeks.

A **suspension culture** consists of single cells and small groups of cells suspended in a liquid medium. Usually, the medium contains the auxin 2,4-D. Suspension cultures must be constantly agitated at 100–250 rpm (revolutions per minute). Suspension cultures grow much faster than callus culture.

Subculturing. If tissue cultures are kept in the same culture vessel, they die in due course of time. Therefore, cells/tissues are regularly transferred into new culture vessels containing fresh media. This process is called **subculturing**. It is important to note that during subculture, only a part of the culture from a vessel is transferred into the new culture vessel.

The callus and suspension cultures may be used to achieve cell biomass production, regeneration of plantlets, production of transgenic plants and isolation of protoplasts.

**in vitro* – outside the living organism and in an artificial environment.

in vivo – within the living organisms.

Differences Between Callus Culture and Suspension Culture

Callus Culture	Suspension Culture
<ol style="list-style-type: none"> 1. In this culture, cell division in explant forms a callus. Callus is an irregular unorganized and undifferentiated mass of actively dividing cells. 2. The culture is maintained on agar medium. 3. The medium contains growth regulators the auxin such as 2,4-D and cytokinin like BAP. 4. Callus is obtained within 2-3 weeks. 5. It does not need to be agitated. 	<ol style="list-style-type: none"> 1. It consists of single cells and small groups of cells suspended in a liquid medium. 2. The culture is maintained in liquid medium. 3. The medium contains growth regulator auxin such as 2,4-D only. 4. Suspension culture grows much faster than callus culture. 5. It must be constantly agitated at 100-250 rpm (revolutions per minute).

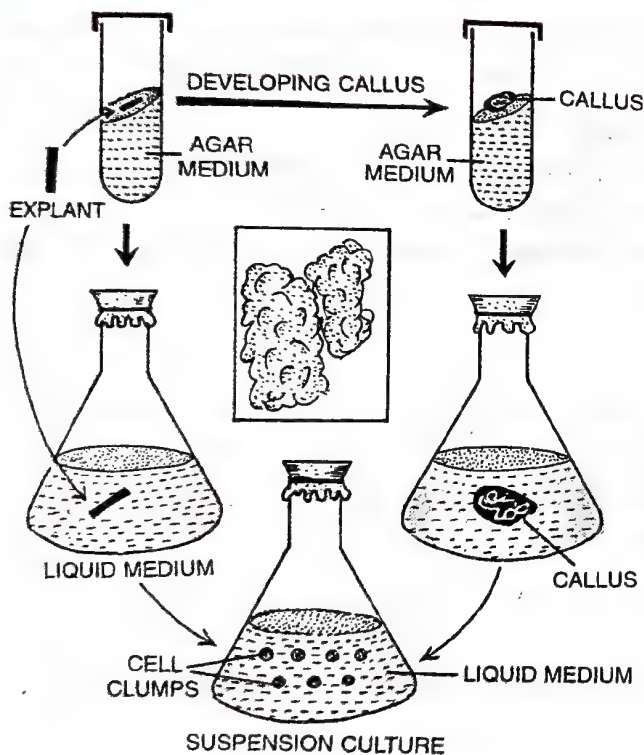


Fig. 9.18. Initiation of callus and suspension cultures.

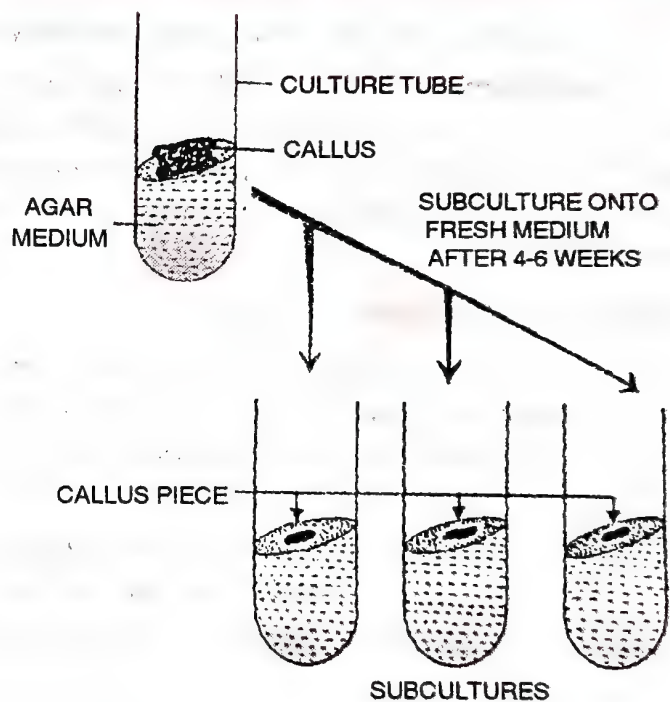


Fig. 9.19. Schematic representation of subculturing.

Single Cell Culture (Cell Cloning)

As stated earlier, cells derived from a single cell through mitosis constitute a **clone** and the process of obtaining clones is called **cloning** (asexual progeny of a single individual make up a clone). There are two popular techniques for single cell culture.

1. **Bergmann's Plating Technique.** This is widely used technique. The cells are suspended in a liquid medium at a cell density that is twice the desired density in the plate. Sterilized agar (Ca 1%) medium is kept melted in a water bath at 35°C. Equal volumes of the liquid and agar media are mixed and spread in Ca 1 mm thick layer in a petridish. The cells remain embedded in the soft agar medium which are observable under a microscope. When large colonies develop they are isolated and cultured separately.

2. **Filter Paper Raft Nurse Tissue Technique.** Single cells are placed on small pieces (8×8 mm) of filter paper, which are placed on top of callus cultures several days in advance. This allows the filter papers to be wetted by the callus tissues. The single cells placed on the filter paper derive their nutrition from the callus. The cells divide and form macroscopic colonies on the filters. The colonies are isolated and cultured.

Shoot and Root Cultures

Shoot culture is promoted by a cytokinin like BAP. However, root culture is promoted by an auxin like NAA (naphthalene acetic acid). The shoot and root cultures are generally controlled by auxin-cytokinin balance. Usually, an excess of auxin promotes root culture, whereas that of cytokinin promotes shoot culture. Roots culture from the lower end of these shoots to give complete plantlets.

Somatic Embryo Culture

A somatic embryo develops from a somatic cell. The pattern of development of a somatic embryo is comparable to that of a zygotic embryo. Somatic embryo culture is induced by a high concentration of an auxin, such as 2,4-D. These embryos develop into mature embryos. Mature somatic embryos or **embryoids** germinate to give complete plantlets.

Establishment in the Field. *The plantlets are removed from culture vessels and established in the field.* This transfer is done by specific procedures called **hardening**. During hardening, plantlets are kept under reduced light and high humidity. Hardening procedures make the plantlets capable of tolerating the relatively harsher environments outside the culture vessels.

Endosperm Culture

Tissue culture methods are also used for culturing endosperm. It is unique because it supplies nutrition to the developing embryo. It is also triploid in its chromosome constitution. Triploid plants are used for the production of seedless fruits (e.g., apple, banana etc.). The technique of endosperm culture involves the following :

- (i) The immature seeds are dissected under aseptic condition. Endosperms along with embryos, are excised. Sometimes, mature seeds can also be used.
- (ii) The excised endosperms are cultured on a suitable medium and embryos are removed after initial growth.
- (iii) The initial callus phase is developed.
- (iv) The shoots and roots may develop and complete triploid plants are formed for further use.

Meristem Culture

Meristem is a localized group of cells, which are actively dividing and undifferentiated but ultimately giving rise to permanent tissue. Although the plant is infected with a virus, yet the meristem is free of virus. Therefore, meristem can be removed and grown *in vitro* to obtain virus free plants. Cultivation of axillary or apical shoot meristems is called **meristem culture**. *The apical or axillary meristems are generally free from virus.* Meristem culture involves the development of an already existing shoot meristem and subsequently, the regeneration of adventitious roots from the developed shoots. It usually does not involve the regeneration of a new shoot meristem. *The explants commonly used in meristem culture are shoot tips and nodal segments.* These explants are cultured on a medium containing a cytokinin (generally BAP). The plantlets thus obtained are subjected to hardening and,

ultimately, established in the field. Meristem culture is carried out in Potato, Banana, Cardamom, Orchids (protocorm stage), Sugarcane, Strawberry, Sweet Potato, etc. It is used in (i) Production of virus-free plants like potato, sugarcane, banana and apple. (ii) Germplasm conservation. (iii) Production of transgenic plants. (iv) Rapid clonal multiplication.

Anther Culture and Haploid Production

An individual/cell having the chromosome number found in the gametes of the species is called **haploid**. Formation of haploid is called **haploid production**. Thus haploid individuals arise from the gametes. A haploid has only one copy of each chromosome. Haploids are sterile and of no direct value.

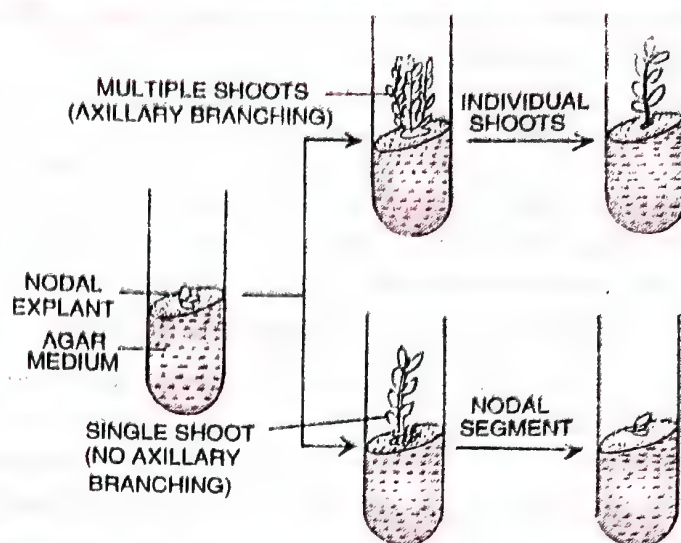


Fig. 9.20. Meristem Culture.

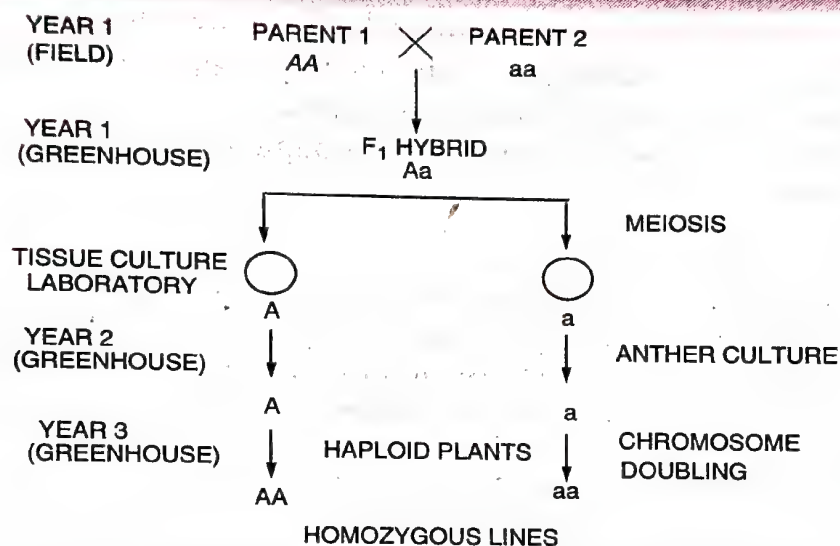


Fig. 9.21. Production of homozygous lines using anther culture. The two parents are shown to differ for only one gene, i.e., AA and aa.

When the chromosome number of a haploid plant is doubled, the plants of normal chromosome number for particular species is obtained. These plants are homozygous and are produced in 2–3 years. The chromosome number of these haploid plants is doubled by using **colchicine** to obtain homozygous plants.

In nature, haploid plants originate from unfertilized egg cells, but in laboratory, they can be produced from both male and female gametes. Anther is the part of the flower of Angiosperms producing pollen (microspores), borne at the end of the stamens and usually consisting of four sporangia. When anthers of some plants are cultured on a suitable medium to produce haploid plants, it is called **anther culture**. The technique was developed by Guha and Maheshwari (1964) who cultured mature anthers of *Datura innoxia*. It is highly useful for the improvement of many crop plants. It is also useful for immediate expression of mutations and quick formation of purelines. This technique was first used in India to

produce haploids of *Datura*. In many plants, haploids are also produced by culturing unfertilized ovaries/ovules. Sometimes, pollen grains are separated from anthers and cultured on suitable medium.

Embryo Culture

Culturing young embryos on a nutrient medium is called *embryo culture*. Young embryos are obtained from the developing seeds. The embryos complete their development on the medium and grow into seedlings. In general, older embryos are more easily cultured *in vitro* than young embryos.

Embryo culture is useful as follows :

(i) *Orchid seeds* do not have any form of stored food. Embryos of such seeds can be cultured to obtain seedlings and maximum seedling formation can be achieved. Embryo culture in orchids can be applied for rapid clonal propagation.

(ii) In certain species, *inhibitors* present in the endosperm or seed coat make the seed dormant. Such embryos can escape dormancy by culturing on a suitable medium.

(iii) In certain *hybrid seeds* developed after interspecific crosses, the endosperm degenerates at an early stage and the young embryo is left with no food, consequently it also dies. Such young embryos can be excised from the seeds and cultured on the nutritive medium. Getting nutrition, they develop into seedlings which can be transplanted in the field.

(iv) A popular example includes hybridization of barley and wheat with *Hordeum bulbosum* leading to the production of haploid barley and haploid wheat respectively. Haploid wheat plants have also been successfully obtained through culture of hybrid embryos from wheat × maize crosses.

Ovule Culture

Ovule culture technique is utilized for raising hybrids which normally fail to develop due to the abortion of the embryos at an early stage. Ovules can easily be excised from the ovary and cultured on the basal medium. The loss of a hybrid embryo due to premature abscission of fruits may be prevented by ovule culture. In some cases, addition of fruit/vegetable juice increase the initial growth.

Ovary Culture

Ovary culture technique has also been successfully employed to raise interspecific hybrids between sexually incompatible species, *Brassica campestris* and *B. oleracea*. Ovaries are excised from the flowers and cultured at the zygote or two-celled proembryo stage for obtaining normal development on culture medium. Sometimes coconut milk when used as a supplement to the medium promote formation of fruits that are larger than those formed *in vivo* (within the living organism). In *Anethum*, addition of kinetin in the medium caused polyembryony which gave rise to multiple shoots.

Micropropagation

Micropropagation is the tissue culture technique used for rapid vegetative multiplication of ornamental plants and fruit trees by using small sized explants. Because of minute size of the propagules in the culture, the propagation technique is named as **mircopropagation**. This method of tissue culture produces several plants. Each of these plants will be genetically identical to the original plant from where they were grown. The geneticali y identical plants developed from any part of a plant by tissue culture/micropropagation are called **somaclones**.

The members of a single somaclone have the same genotype. This micropropagation is also known as **somaclonal propagation**. It is the only process adopted by Indian plant biotechnologists in different industries mainly for the commercial production of ornamental plants like lily, orchids, *Eucalyptus*, Cinchona, Blueberry, etc. and fruit trees like tomato, apple, banana, grapes, potato, citrus oil palm, etc.

There are four defined steps in micropropagation method. These are:

- (i) **Initiation of culture**— from an explant like shoot tip on a suitable nutrient medium.
- (ii) **Shoot formation**— multiple shoots formation from the cultured explant.
- (iii) **Rooting of shoots**— rooting of *in vitro* developed shoots.
- (iv) **Transplantation**— the hardening of tissue culture raised plants and subsequent transplantation to the field.

Advantages of Micropropagation. These are as follows :

1. It helps in rapid multiplication of plants.
2. A large number of plantlets are obtained within a short period and from a small space.
3. Plants are obtained throughout the year under controlled conditions, independent of seasons.
4. Sterile plants or plants which cannot maintain their characters by sexual reproduction are multiplied by this method.
5. It is an easy, safe and economical method for plant propagation.
6. In case of ornamentals, tissue culture plants give better growth, more flowers and less fall-out.
7. Genetically similar plants (somaclones) are formed by this method. Therefore, desirable characters (genetope) and desired sex of superior variety are kept constant for many generations.
8. The rare plant and endangered species are multiplied by this method and such plants are saved.

Regeneration of Plantlets

1. **Preparation of Suitable Nutrient Medium.** Suitable nutrient medium as per objective of culture is prepared and transferred into suitable containers.
2. **Selection of Explants.** Selection of explants such as shoot tip should be done.
3. **Sterilisation of Explants.** Surface sterilization of the explants by disinfectants and then washing the explants with sterile distilled water is essential.
4. **Inoculation.** Inoculation (transfer) of the explants into the suitable nutrient medium (which is sterilized by filter-sterilized to avoid microbial contamination) in culture vessels under sterile conditions is done.
5. **Incubation.** Growing the culture in the growth chamber or plant tissue culture room, having the appropriate physical condition (*i.e.*, artificial light ;16 hours of photoperiod), temperature (-26°C) and relative humidity (50–60%) is required.
6. **Regeneration.** Regeneration of plants from cultured plant tissues is carried out.
7. **Hardening.** Hardening is gradual exposure of plantlets to an environmental conditions.
8. **Plantlet Transfer.** After hardening plantlets transferred to the green house or field conditions following acclimatization (hardening) of regenerated plants.

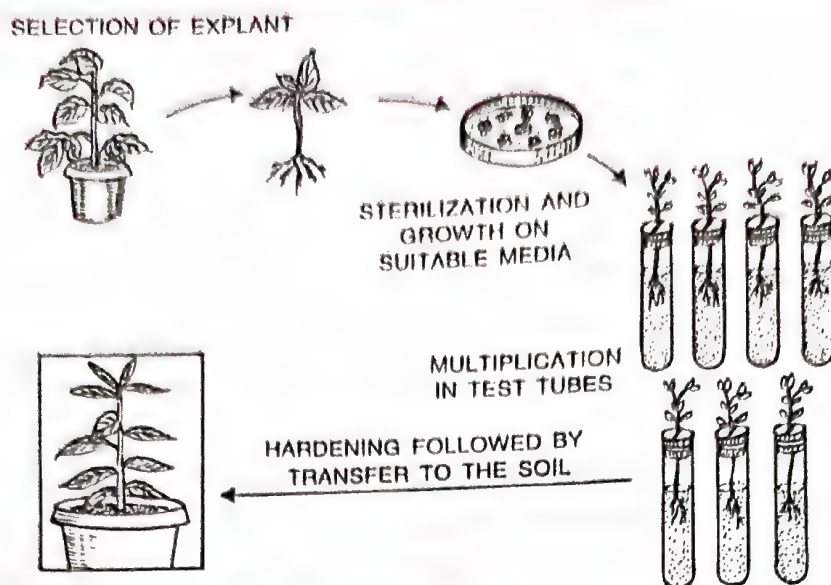


Fig. 9.22. Regeneration of whole plants using tissue culture technique.

Protoplast Culture and Somatic Hybridisation

When a hybrid is produced by fusion of somatic cells of two varieties or species, it is known as **somatic hybrid**. The process of producing somatic hybrids is called **somatic hybridisation**.

First, the cell wall of the plant cells are removed by digestion with a combination of pectinase and cellulase. The plant cells without cell wall are called **protoplasts**.

The protoplasts of the two plants are brought together and made to fuse in a solution of **polyethylene glycol (PEG)** or sodium nitrate. The fusion of protoplasts with the help of chemicals is called **chemofusion**. Fusion of protoplasts with the help of high voltage pulse is known as **electrofusion**. The fusion of protoplasts not only involves the fusion of their cytoplasm but also their nuclei. The fused protoplasts are allowed to grow on culture medium. Soon they develop their own walls when they are called **somatic hybrid cells**. The hybrid cells give rise to callus. Callus later differentiates into new plant which is somatic hybrid between two plants. Somatic hybrids in plants were first obtained between two species of Tobacco (*Nicotiana glauca* and *N. langsdorffii*) by Carlson *et al* in 1972. Successful somatic hybrids have also been got from different species of *Brassica*, *Petunia*, and *Solanum*. **Pomato** is somatic hybrid between Potato and Tomato that belong to two different genera and **Bomato** is somatic hybrid between Brinjal and Tomato. Somatic hybrids are also produced between rice and carrot. The hybrid plant bears both fruits and tubers of the two parents.

(a) Protoplast technology has opened up avenues for development of hybrids of even asexually reproducing plants.

(b) There is a distinct possibility of development of new crop plants, e.g., Pomato.

(c) Somatic hybrids may be used for the production of useful allopolyploids (Individuals produced by interspecific polyploidy).

(d) Genetic manipulations can be carried out more rapidly when plant cells are in protoplast state. New genes can be introduced (e.g., male sterility, herbicide resistance). Mutations will be easier.

If we conclude, plant tissue culture is a broad term used to define different types of *in vitro* plant culture. It may be recognized in the following types. Each type can result in a whole plant. (1) Callus culture — culture of differentiated tissue from an explant that dedifferentiates. (2) Cell culture — culture of cells or cell aggregates (small clumps of cells) in liquid medium. (3) Protoplast culture — culture of plant cells with their cell walls removed. (4) Embryo culture — culture of isolated embryos. (5) Seed culture — culture of seeds to generate plants. (6) Organ culture — culture of isolated plant organs such as anthers, roots, buds and shoots.

Artificial Seeds

There are many plants which neither bear seeds nor produce a small quantity of seeds. To overcome this problem the concept of **artificial seeds** has become popular, where somatic embryos are encapsulated in a suitable matrix composed of sodium alginate, along with substances like mycorrhizae, herbicides, fungicides and insecticides. The technique involved in the production of artificial seeds is based on cellular totipotency and somatic embryogenesis.

An artificial seed is a bead of gel containing a somatic embryo (or shoot bud) and the nutrients, growth regulators, antibiotic, etc. needed for the development of a complete plantlet. Artificial seeds may be produced using one of the following two ways : **desiccated systems** and **hydrated systems**. In the desiccated systems the somatic embryos (SEs) are first hardened to withstand desiccation and then are encapsulated.

In the hydrated systems, the beads become hardened as calcium alginate is formed, after about 20–30 minutes the artificial seeds are removed, washed with water and used for planting. Hydrated artificial seeds become dry rapidly in the open air. Therefore, hydrated artificial seeds have to be planted soon after they are produced.

In India, this technique of synthetic seeds is being done for sandalwood and mulberry at BARC (Bhaba Atomic Research Centre), Mumbai.

Advantages (i) They can be directly sown in the soil like natural seeds. (ii) They can be stored upto a year without loss of viability. (iii) They are easy to handle, and useful as units of delivery.

The only disadvantage of artificial seeds is the high cost of their production.

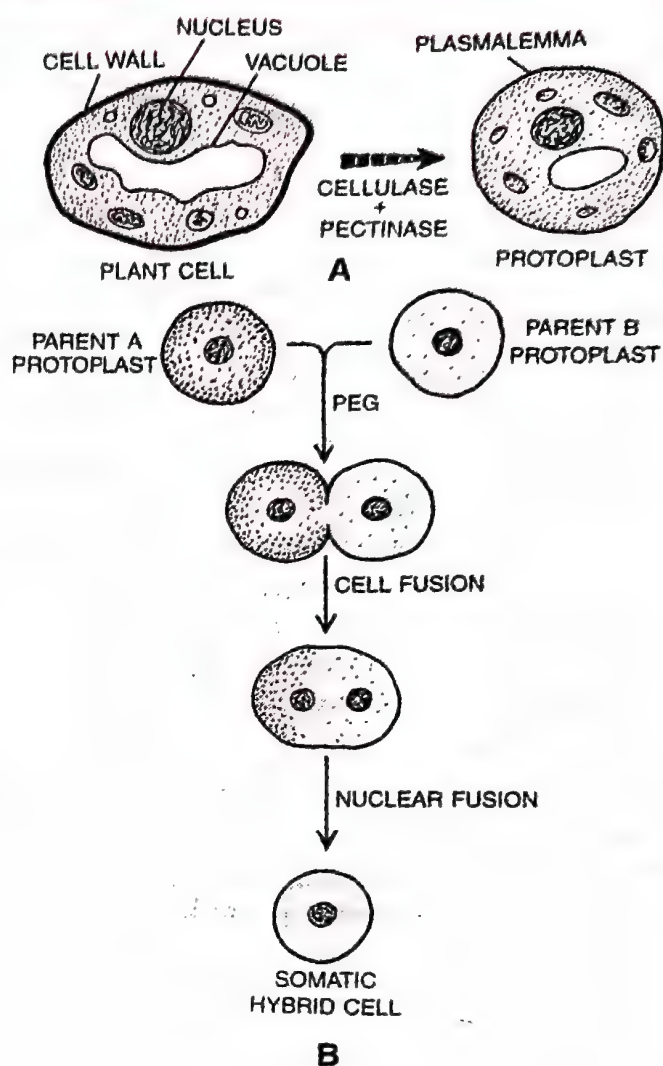


Fig. 9.23. Somatic hybridisation. A, Production of protoplasts using a combination of pectinase and cellulase. B, Protoplast fusion induced by PEG ultimately yields somatic hybrid cells.

Applications of Plant Tissue Culture

The use of plant cells to generate useful products and/or services constitutes **plant biotechnology**. In plant biotechnology, the useful product is a plantlet. The plantlets are used for the following purposes.

1. **Rapid Clonal Propagation.** A **clone** is a group of individuals or cells derived from a single parent individual or cell through asexual reproduction. All the cells in callus or suspension culture are derived from a single explant by mitotic division. Therefore, all plantlets regenerated from a callus/suspension culture generally have the same genotype and constitute a clone. These plantlets are used for rapid clonal propagation. This is done in oil palm.

2. **Somaclonal Variation.** Genetic variation present among plant cells of a culture is called **somaclonal variation**. The term somaclonal variation is also used for the genetic variation present in plants regenerated from a single culture. This variation has been used to develop several useful varieties.

3. **Transgenic Plants.** A gene that is transferred into an organism by genetic engineering is known as **transgene**. An organism that contains and expresses a transgene is called **transgenic organism**. The transgenes can be introduced into individual plant cells. The plantlets can be regenerated from these cells. These plantlets give rise to the highly valuable transgenic plants.

4. **Mutations.** Mutagens are added to single cell liquid cultures for induction of mutations. The cells are washed and transferred to solid culture for raising mutant plants. Useful mutants are selected for further breeding. Tolerance to **stress** like pollutants, toxins, salts, drought, flooding, etc. can also be obtained by providing them in culture medium in increasing dosage. The surviving healthy cells are taken to solid medium for raising resistant plants.

5. **Resistance to Weedicides.** It is similar to induction of mutations. Weedicides are added to culture initially in very small concentrations. Dosage is increased in subsequent cultures till the desired level of resistance is obtained. The resistant cells are then regenerated to form plantlets and plants.

ADDITIONAL INFORMATION

- **Branch of medicine** that deals with the prevention, treatment and cure of animal diseases is called **veterinary medicine**.
- **Androgenesis** is the production of haploid plants by germination of young pollen grains from male gametophyte.
- **Gynogenesis** is the development of plants from unfertilized cells of female gametophyte in ovary and ovules in tissue culture with the help of MCPA.
- The important plant breeding centres in India are:
 - (i) G.B. Pant Agricultural University, Pantnagar.
 - (ii) Narendra Dev University, Kumarganj.
 - (ii) Punjab Agricultural University, Ludhiana.
 - (iv) Indian Agricultural Research Institute (IARI), New Delhi.
 - (v) Central Rice Research Institute, Cuttack.
 - (vi) National Botanical Research Institute, Lucknow.
 - (vii) Forest Research Institute, Dehradun.
 - (viii) Central Potato Research Institute, Shimla.
 - (ix) Sugarcane Breeding Institute, Coimbatore.
- **Pebrine** (disease of silkworm) is caused by protozoan *Nosema bombycis*.
- **Etiology (or Aetiology)** deals with the study of various causes of the disease.
- **Epidemiology** deals with the study of factors affecting the outbreak of an infectious disease.
- **Inoculum** is that portion of individual patho-

- gen that is brought into contact with the host in order to cause the disease.
- Central Food Technology Research Institute, Mysore.
 - **Father of Green Revolution.** Norman E. Borlaugh. Dr Borlaugh a botanist received Nobel Prize for Peace.
 - **Father of Green Revolution in India.** M.S. Swaminathan.
 - **World Food Day.** 16th October.
 - Father of embryology in India – **Panchanan Maheshwari.**
 - A neurotoxin is found in the seeds of "Khesari" (*Lathyrus sativa*).
 - **PCT.** Patent Co-operation Treaty.
 - **IPM.** Integrated Pest Management.
 - **Oldest Cereal Crop.** Barley.
 - A safe herbal pesticide from garlic and chillies has been developed in Pune (Maharashtra).
 - Scientists at CDRI in Lucknow developed **Biocide** from the microorganism *Bacillus sphaericus* which is highly effective formulation to control the mosquito menace.
 - Lysine rich varieties of maize, viz., 'Shakti Rattan' and "Protina" have been developed in India.
 - The first milk cooperative called AMUL, was setup by **Dr. Verghese Kurien.** He is considered as Father of white revolution in India.
 - International Rice Research Institute (IRRI) is located in Philippines.
 - **Sericulture.** Silk is the product of salivary gland of larva.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. Explain in brief the role of animal husbandry in human welfare.
✓ Animal husbandry plays a very important role in human welfare by providing us milk, eggs, meat, wool, silk, honey, wax, hides, etc. A number of animals like horse, camel, ass carry men and materials. Rearing of animals provides useful employment to many persons.
2. If your family owned a dairy farm, what measures would you undertake to improve the quality and quantity of milk production ?
✓ Following measures are to be undertaken to improve the quality and quantity of milk production. (i) There should be selection of good breed. (ii) Cattle shed should be spacious, roofed and airy. (iii) The feeding should be carried out in scientific manner with special emphasis on quality and quantity of fodder. (iv) Cattle should be regularly brushed, massaged and cleaned. (v) Proper sanitation measures are required in the cattle shed. (vi) Vaccination and proper medical treatment are essential.
3. What is meant by the term 'breed' ? What are the objectives of animal breeding ?
✓ **Breed.** A breed is a group of animals of the same species related by descent and are similar in most of their characteristics.
Objectives of animal breeding. (i) Increasing the quantity of yield. (ii) Improving the quality of the products. (iii) Resistance to various diseases.
4. Name the methods employed in animal breeding. According to you which of the methods is best ? Why ?
✓ Animal breeding is of the following types. (1) Inbreeding, (2) Out breeding. Out breeding is of three types : (i) Out crossing, (ii) Cross breeding and (iii) Interspecific hybridisation. Out of these methods cross-breeding is best because it allows the desirable qualities of two different breeds.
5. What is apiculture ? How is it important in our lives ?
✓ Apiculture (bee keeping) is the rearing, caring and management of honey bees for obtaining honey and wax. Honey is a food substance of high nutritive value and it is also medically important. Bee wax is used in the preparation of cosmetics and polishes.
6. Discuss the role of fishery in enhancement of food production.
✓ Fishery industry has increased huge amount of food products, therefore, it is called the Blue Revolution. It is the main source of livelihood in coastal areas.
7. Briefly describe various steps involved in plant breeding.
✓ Following steps are involved in plant breeding. (i) Collection of germplasm. (ii) Evaluation and selection of parents. (iii) Cross hybridisation among the selected parents. (iv) Selection and testing of superior recombinants. (v) Testing release and commercialisation of new cultivars.
8. Explain what is meant by biofortification ?
✓ Breeding of crops with higher levels of vitamins and minerals or higher protein and healthier fats is called biofortification.

9. Which part of a plant is best suited for making virus-free plants and why ?
✓ The apical or axillary meristems are best suited for making virus free plants because they are generally free from virus.
10. What is the major advantage of producing plants by micropropagation ?
✓ Large number of plants are obtained in very short durations. Plants formed by micropropagation are identical.
11. Find out what the various components of the medium used for propagation of an explant *in vitro* are?
✓ Nutrient medium should provide carbon source such as sucrose, inorganic salts, vitamins, amino acids and growth regulators like auxins, cytokinins, etc.
12. Name any five hybrid varieties of crop plants which have been developed in India.
✓ Wheat varieties –*Sonalika*, and *Kalyan Sona*, Rice varieties –*Jaya* and *Ratna* and Chilli–*Pusa Sadabahar*.

TEXT QUESTIONS

One Mark Questions (With Answers)

1. Name two plants which have been produced by artificial selection.
✓ Wheat and Maize.
2. Name two diseases of poultry.
✓ Ranikhet and tick fever.
3. Which is the oldest method of crop improvement ?
✓ Selection.
4. What is emasculation ?
✓ Emasculation is removal of anthers from a bisexual flower.
5. Name the alkaloïd that prevents the formation of spindle apparatus during mitosis.
✓ Colchicine
6. Name the improved variety of wheat that is developed through hybridisation that took 12 years.
✓ Wheat variety HUW 468.
7. Name two lysine-rich varieties of maize.
✓ Shakti, Rattan, Protina (any two)
8. Name two growth regulators commonly used in plant tissue culture.
✓ (i) 2, 4 dichlorophenoxy acetic acid (2, 4-D) (ii) Benzylaminopurine (BAP)
9. Define somaclonal variation.
✓ The genetic variation found among the plant cells in a culture is called somaclonal variation.
10. What is somatic embryo ?
✓ A somatic embryo is an embryo that develops from somatic cell (s).
11. Who started the technique of plant tissue culture ?
✓ Haberlandt
12. Name the chemical used for doubling the chromosome number.
✓ Colchicine
13. Name the fungus (apart from yeast) used for the production of SCP.
✓ *Fusarium graminearum*
14. Which parents reproduce a mule?
✓ A mule is a hybrid of a male donkey and the mare (female horse).
15. List any two economically important products for humans obtained from *Apis indica*. (CBSE 2008)
16. Which part of the plant is best suited for making virus free plants ?
17. What is meant by biofortification ?
18. Name the enzyme commonly used to dissolve the bacterial cell wall.
19. How are somatic hybrids obtained?
20. Mention the role of 'genetic mother' in MOET.
21. A herd of cattle is showing reduced fertility and productivity. Provide one reason and one suggestion to overcome this problem.

(CBSE 2014)
(CBSE 2016)
(CBSE 2017)

Two Mark Questions (With Answers)

1. What are intervarietal and interspecific hybridisations ?
✓ Intervarietal hybridisation is a cross between the two varieties of the same species whereas interspecific hybridisation is a cross between the different species of the same genus.
2. Expand MOET. Explain the procedure of this technology in cattle improvement. (CBSE 2008)
3. What is the major advantage of producing plants by micropropagation?
4. Explain Biomodified foods.
5. Write differences between the inbreeding & outbreeding. (CBSE 2010)
6. Explain the advantage of cross breeding of the two species of sugarcane in India. (CBSE 2011)
7. How is 'Rosie' considered different from a normal cow ? Explain. (CBSE 2011)
8. Name the following :
 - (a) The semi-dwarf variety of wheat which is high-yielding and disease-resistant.
 - (b) Any one inter-specific hybrid mammal. (CBSE 2012)
9. Write the name of the following :
 - (a) The most common species of bees suitable for apiculture.
 - (b) An improved breed of chicken. (CBSE 2012)
10. Why are beehives kept in crop field during flowering period? Name any two crop fields where this is practiced. (CBSE 2014)
11. (a) Why are the plants raised through micropropagation termed as somaclones ?
(b) Mention two advantages of this technique. (CBSE 2015)
✓ (a) The method of growing or producing thousands of plants through tissue culture is called **micropropagation**.
The plants produced from tissue culture are genetically identical to the original plant from which they are grown, so they are called **somaclones**.
(b) Advantages of tissue culture are :
 - (i) More number of plants can be produced in a short time.
 - (ii) Disease-free plants can be developed from diseased plants.
 - (iii) Seedless plants can be multiplied.

Three Mark Questions (Short Answer Type)

1. Name three common fresh water and three marine edible fishes.
2. Mention the strategy used to increase homozygosity in cattle for desired traits. (CBSE 2009)
3. MOET is a good technology to increase the herd size of high yielding cattle. How is it done ? Explain the procedure. (CBSE 2010)
4. Scientists have succeeded in recovering healthy sugarcane plants from a diseased one.
 - (a) Name the part of the plant used as explant by the scientists.
 - (b) Describe the procedure the scientists followed to recover the healthy plants.
 - (c) Name this technology used for crop improvement. (CBSE 2011)
5. State the disadvantage of inbreeding among cattle. How it can be overcome? (CBSE 2014)
6. Enumerate any six essentials of good, effective dairy farm management practices. (CBSE 2015)
7. (a) Write the two limitations of traditional breeding technique that led to promotion of micro propagation.
(b) Mention two advantages of micro propagation.
(c) Give two examples where it is commercially adopted. (CBSE 2016)
8. (a) What is inbreeding depression ?
(b) Explain the importance of "selection" during inbreeding in cattle. (CBSE 2017)
9. (a) Write the desirable characters a farmer looks for in his sugarcane crop.
(b) How did plant breeding techniques help North Indian farmers to develop cane with desired characters ? (CBSE 2017)

Five Mark Questions (Long Answer Type)

1. What are Hybrids ? Briefly describe their production and importance in boosting animal and crop productions.
2. (a) Explain how to overcome inbreeding depression in cattle.

- (b) List three advantages of inbreeding in cattle.
 (c) Name an improved breed of cattle. (CBSE 2013)
3. (a) What is plant breeding? List the two steps the classical plant breeding involves.
 (b) How has the mutation breeding helped in improving crop varieties? Give one example where this technique has helped. (CBSE 2013)
 (c) How has the breeding programme helped in improving the public nutritional health? State two examples in support of your answer. (CBSE 2013)
4. (a) Plant an experiment and prepare a flow chart of the steps that you would follow to ensure that the seeds are formed only from the desired sets of pollen grains. Name the type of experiment that you carried out. (CBSE 2015)
 (ii) Write the importance of such experiments.

Value Based Questions with Answers

1. Doctor has recommended *Spirulina* supplement to Kavita's father because he is weak and does not lead normal life.
 Read the above passage and answer the following questions.
 (i) Why did doctor recommend *Spirulina*.
 (ii) Is it also useful for Kavita.
 (iii) Can it be produced in the laboratory?
 ✓ (i) Because it is rich in protein.
 (ii) It is beneficial for growth and development.
 (iii) It can be produced in the laboratory throughout the year. It belongs to the category of single cell protein (SCP).
2. Rakesh asked the following questions from his father and requested him to answer.
 (i) Please tell me two superior varieties of cows.
 (ii) What are the products obtained from bee keeping.
 (iii) What is floriculture.
 (iv) What are the methods of increasing commercial production of plants?
 ✓ (i) Jersey and Holstein.
 (ii) Honey and wax.
 (iii) Floriculture is growing of ornamental flowers for commercial purpose.
 (iv) Plant Tissue Culture is one of the methods widely used for this purpose especially for orchids.

Multiple Choice Questions

- (1) Percentage composition of fibroin and sericin in silk is (a) 50 : 40 (b) 80 : 20 (c) 30 : 70 (d) 40 : 60. (WB JEE 2010)
- (2) An improved variety of transgenic basmati rice (a) does not require chemical fertilizers and growth hormones (b) gives high yield and is rich in vitamin A (c) is completely resistant to all insect pests and diseases of paddy (d) gives high yield but has no characteristic aroma. (CBSE PMT Prelims 2010)
- (3) Which of the following are used in gene cloning ? (a) Nucleoids (b) Lomasomes (c) mesosomes (d) plasmids. (CBSE PMT Mains 2010)
- (4) Triticale is produced by the crossing of (a) wheat and rye (b) wheat and maize (c) wheat and barley (d) rye and maize. (AFMC 2010)
- (5) Which one of the following diseases is caused by *Nosema bombycis* in mulberry silkworm ?
 (a) Muscardine (b) Pebrine (c) Grasserie (d) Flacherie. (Karnataka CET 2010)
- (6) Bovine spongiform encephalopathy is a disease caused by prions in a (a) sheep (b) cow (c) potato (d) man. (Karnataka CET 2010)
- (7) "Jaya" and "Ratna" developed for green revolution in India are the varieties of (a) maize (b) rice (c) wheat (d) bajra. (AIPMT (Prelims) 2011)
- (8) "Himgiri" developed by hybridisation and selection for disease resistance against rust pathogens is a variety of (a) chilli (b) maize (c) sugarcane (d) wheat. (AIPMT (Prelims) 2011)
- (9) Which one of the following shows maximum genetic diversity in India ? (a) Groundnut (b) Rice (c) Maize (d) Mango. (AIPMT (Prelims) 2011)

- (10) Somatic embryo can be developed in plant tissue culture from (a) a somatic cell (b) single germ line cell (c) any type of fertilized cell (d) anthers. (J & K CET 2011)
- (11) Pieces of plant used in tissue culture is called (a) explant (b) somaclone (c) inoculant (d) clone. (West Bengal JEE 2011)
- (12) The term "molecular scissors" generally refers to (a) DNA polymerases (b) RNA polymerases (c) restriction endonucleases (d) DNA ligases. (AMU (Medical) 2011)
- (13) Which one of the following is breed of cattle ? (a) Ayrshire (b) Ghagus (c) Kadakanath (d) Scampi. (AMU 2012)
- (14) Which one of the following poultry birds is not an english breed ? (a) Sussex (b) Australorp (c) Orpington (d) Minorca. (West Bengal JEE 2012)
- (15) Human proteins can be produced in the milk or semen of farm animals. True or false ?
(a) True (b) false, proteins cannot be produced in milk (c) false, proteins cannot be produced in semen (d) false, animals are not used for protein production. (J & K CET 2012)
- (16) An example for semi dwarf variety of wheat (a) IR – 8 (b) Sonalika (c) Triticum (d) Saccharum. (HP PMT 2012)
- (17) Explant required for virus free culture is (a) root (b) shoot tip (c) leaf (d) leaf and root. (HP PMT 2012)
- (18) Hallikar draught breed of cattle is found in (a) Karnataka (b) Gujarat (c) Andhra Pradesh (d) Madhya Pradesh. (AMU 2013)
- (19) Amritmahal is a/an (a) dual purpose breed (b) exotic breed (c) cross breed (d) draught breed. (Karnataka CET 2013)
- (20) Triticale is obtained by crossing wheat with (a) oat (b) maize (c) barley (d) rya. (J & K CET 2013)
- (21) The "hissardale" is a breed of sheep developed by crossing between (a) bikaneri ewes and merino rams (b) merino ewes and bikaneri rams (c) deccani ewes and bikaneri rams (d) merino ewes and apennine rams. (AMU 2014; KCET 2015)
- (22) Outbreeding is an important strategy of animal husbandry because it (a) helps in accumulation of superior genes (b) is useful in producing purelines of animals (c) is useful in overcoming inbreeding depression (d) exposes harmful recessive genes that are eliminated by selection. (AIPMT 2015)
- (23) Semi-dwarf rice variety IR-8 was developed in (a) Taiwan (b) Philippines (c) India (d) China. (MH CET 2015)
- (24) To induce formation of organs in a callus it is necessary to provide
(a) growth hormones (b) water (c) soil (d) antibiotics (MH CET 2015)
- (25) The technique of producing large number of genetically similar plants within short time by tissue culture is called (a) organogenesis (b) somatic hybridisation (c) micropropagation (d) protoplast culture. (MH CET 2015)
- (26) What is not true about emasculation of a flower while performing an artificial cross ? (a) It is removal of anthers from flower (b) It is done before anthesis (c) It is to avoid self pollination (d) It is done in flowers of plants selected as male parent. (MH CET 2015)
- (27) Pusa Shubhra is a variety of (a) cauliflower (b) chilli (c) wheat (d) cabbage. (MH CET 2015)
- (28) Following are all breeds of cows except (a) Jersey (b) Nagpuri (c) Sahiwal (d) Sindhi. (MH CET 2015)
- (29) Interspecific hybridisation is the mating of
(a) animals within same breed without having common ancestors (b) two different related species (c) superior males and females of different breeds (d) more closely related individuals within same breed for 4-6 generations. (NEET-II-2016)

Assertion and Reason Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—

- (a) If both A and R are true and R is the correct explanation of A
(b) If both A and R are true and R is not the correct explanation of A
(c) If A is true but R is false
(d) If both A and R are false.

1. **Assertion:** One of the major crops that originated in the new world is wheat.

Reason: Wheat is cultivated in large scale in Central Asia.

A B C D

2. **Assertion:** Genetic diversity of our crop plants must be conserved.
Reason: Genetic diversity is being or is likely to be used in the improvement of domesticated plants.
 A B C D
3. **Assertion:** Cryopreservation is one of the best methods of germplasm storage.
Reason: In cryopreservation, the cells remain in a state of suspended animation.
 A B C D
4. **Assertion:** Foot and mouth disease causes ulceration in mouth and hoof clefts.
Reason: Foot and mouth disease is highly contagious.
 A B C D
5. **Assertion (A)** Somoclonal variations may be present in plants produced from callus.
Reason (B) Somoclonal variations are caused due to recombination during meiosis.
 (EAMCET (Andhra Pradesh) 2009)

ANSWERS

Multiple Choice Questions

- (1) —b (2) —b (3) —d (4) —a (5) —b (6) —b (7) —b (8) —d (9) —b (10) —a
 (11) —a (12) —c (13) —a (14) —d (15) —a (16) —b (17) —b (18) —a (19) —d (20) —(d)
 (21) —a (22) —c (23) —b (24) —a (25) —c (26) —d (27) —a (28) —b (29) —b

Assertion and Reason Type Questions

- (1) —D (2) —A (3) —A (4) —B (5) —C

Microbes or microorganisms are small organisms which are not visible to naked eye because they have a size of 0.1 mm or less. They can, therefore, be seen only under the microscope. Microbes are present everywhere inside soil, in all types of waters, in air, on dust particles, inside and outside our bodies as well as other animals and plants. They even occur in most inhospitable places where no other life forms can exist — in snow, inside thermal vents or inside geysers (with temperature of 100°C), deep inside soil, highly acidic habitats, Microbes belong to diverse groups of organisms — bacteria, fungi, protozoa, microscopic plants. Viruses, viroids and prions are also included amongst microbes. They are infectious agents. Viruses are nucleoprotein entities, Viroids are made up of only nucleic acids. Prions are proteinaceous infectious agents. The three cannot be cultured in cell free colonies, e.g., bacteria, fungi. The colonies can be seen with naked eyes. They are useful in the study of various aspects of microorganisms.

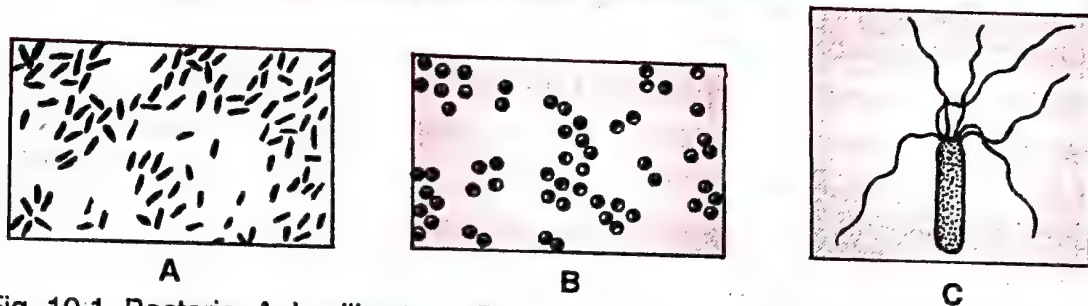


Fig. 10.1. Bacteria. A, bacillus type. B, coccus type. C, a flagellate bacillus bacterium.

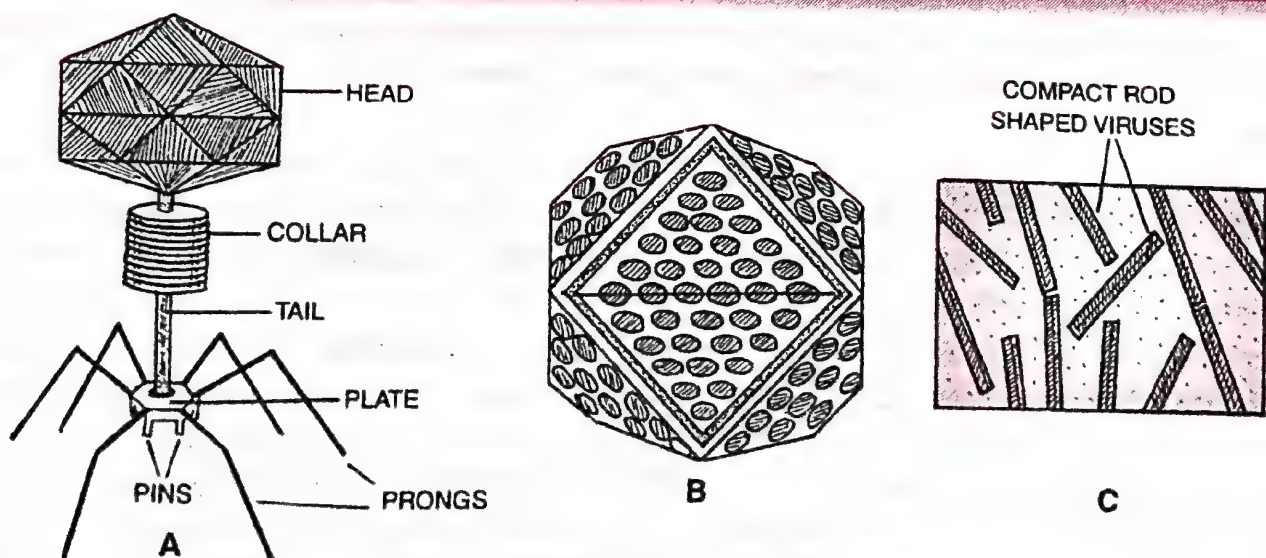


Fig. 10.2. Viruses. A, bacteriophage. B, Adenovirus, the common cold virus. C, TMV (Tobacco Mosaic Virus).

While microbes are causal agents of most of the infectious diseases, they have also been in use by humans and nature in many important processes in homes, industries, agricultures and sewage treatment. Rather, microbes become part of many useful articles used by early humans like fermented honey (alcoholic drink mead), wines, bread, curd, cheese, separation of plant fibres, etc.

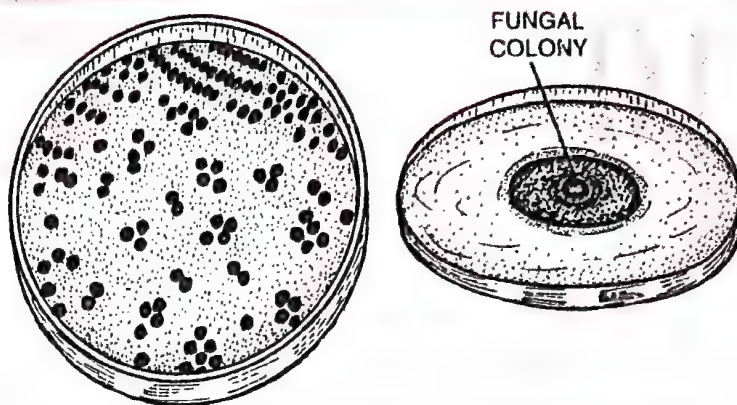


Fig. 10.3. Microbe colonies. A, bacterial colonies. B, a fungal colony.

I. Microbes in Household Products

1. **Dairy Products.** Lactic acid bacteria (LAB) like *Lactobacillus* are added to milk. It converts lactose sugar of milk into lactic acid. Lactic acid causes coagulation and partial digestion of milk protein casein. Milk is changed into curd, yoghurt and cheese. The starter or inoculum used in preparation of milk products actually contains millions of LAB.

(i) **Curd.** Indian curd is prepared by inoculating skimmed and cream milk with *Lactobacillus acidophilus* at a temperature of about 40°C or less. Curd is more nutritious than milk as it contains a number of organic acids and vitamins including B₁₂. LAB present in curd also checks growth of disease causing microbes in stomach and other parts of digestive tract. Curd is eaten as such, salted or sweetened. Curd is churned to prepare lassi. It is also used to obtain butter and butter milk.

(ii) **Yoghurt (= yogurt).** It is produced by curdling milk with the help of *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. The temperature is maintained at about 45°C (40°–46°C) for four hours. It has a flavour of lactic acid and acetaldehyde. Yoghurt is often sweetened and mixed with fruit.

(iii) **Butter Milk.** It is acidulated product which is formed by inoculating skimmed milk with starter culture of *Streptococcus cremoris*, *S. lactis*, *Lactobacillus acidophilus*, *Leuconostoc* species at 22°C for 18 hours. Acidulated liquid left after churning of butter from curd is also called butter milk.

(iv) **Sour Cream.** Cream obtained by churning of milk is inoculated with *Streptococcus lactis* for producing lactic acid and *Leuconostoc cremoris* for imparting the characteristic flavour.

(v) **Cheese.** It is one of the oldest milk products prepared with the help of microbes. The curd is separated from liquid part or whey to form cheese. Depending upon water content, cheese is of three types –soft (50–80% water), semihard (about 45% water) and hard (less than 40% water).

The method of preparing cheese with the help of microbes was known in Asia and Europe long before Christ. There are several varieties of cheese with different texture, flavour and taste. Curdling is done with the help of lactic acid bacteria and enzyme rennin (= Casein coagulase, chymosin), rennet (from Calf's stomach) or fruit extract of *Withania coagulans*. In preparation of raw cheese milk is curdled with the help of lactic acid bacteria. The curd is heated gently to separate cheese from whey. Any liquid left in cheese is allowed to drain by hanging it in cloth. **Unripened or Cottage cheese** is prepared by single step fermentation which involves inoculation of skimmed milk with cheese culture (e.g., *Lac-*

tobacillus, *Acetobacter*, *Saccharomyces*, *Rhizopus*, *Amylomyces*) and addition of rennin or rennet after 1–2 hours. Curd is placed in cloth lined porous containers for draining out whey. **Ripened cheese** is prepared from unripened cheese by first dipping in brine, wiping and then maturation with different strain of bacteria and fungi. It takes 1–16 months for ripening. Large holed swiss cheese is ripened with the help of CO₂ producing (causing holes) bacterium called *Propionibacterium sharmanii*. Roquefort cheese uses *Penicillium roqueforti* while Camembert cheese employs *Penicillium camemberti* for ripening.

2. **Bread.** Selected strains of Baker's Yeast, *Saccharomyces cerevisiae*, are grown on molasses. When sufficient growth has occurred, Baker's Yeast is harvested and converted into either powder or cakes. A small quantity of Baker's Yeast is added to wheat flour. The same is kneaded. The kneaded flour is kept at a warm temperature for a few hours. It swells up. The phenomenon is called **leavening**. Leavening is caused by secretion of three types of enzymes by yeast. They are amylase, maltase and zymase. Amylase causes breakdown of a small quantity of starch into maltose sugar. Maltase converts maltose into glucose. Glucose is acted upon by zymase. Zymase is a complex of several enzymes of anaerobic respiration which brings about fermentation. Fermentation of glucose mainly forms ethyl alcohol and carbon dioxide. The two cause swelling or leavening of the dough. The leavened dough is baked. Both carbon dioxide and ethyl alcohol evaporate making the bread porous and soft.

3. **Dosa, Uppma and Idli.** They are fermented preparation of rice and Black Gram (vern. Urad). The two are allowed to ferment for 3–12 hours with air borne *Leuconostoc* and *Streptococcus* species of bacteria. CO₂ produced during fermentation causes puffing up of the dough.

4. **Jalebi.** The semi-liquid dough of fine flour of Wheat is fermented with yeast, fried in the form of coils and dipped in sugar syrup to obtain Jalebi. **Imriti** is similarly prepared from Black Gram flour.

5. **Other Foods.** **Tempeh** (Indonesia), **Tofu** (Japanese) and **Sufu** (Chinese) are fermented foods obtained from soyabean. **Soy sauce** is brown flavoured salty sauce fermented from soyabean and wheat. Tender **bamboo shoots** are used as vegetable directly as well as after fermentation. Several types of **sausages** are prepared by fermentation and curing of fish and meat. **Sauerkraut** is finely chopped fermented and pickled cabbage.

6. **SCP (Single cell protein).** It is the production of microbial biomass as supplementary food for humans and animals. The common SCP are *Spirulina*, Yeast and *Fusarium graminearum*. Processing is required. SCP is rich in high quality protein, vitamins and minerals but poor in fat. Besides providing much needed proteins, SCP is useful in reducing environmental pollution as it is often grown over medium having organic wastes from agriculture and industries.

7. **Toddy.** It is a traditional drink of some parts of South India which is made by fermentation of sap of palms. A common source is tapping of unopened spadices of coconut. It is a refreshing drink which can be heated to produce jaggery or palm sugar. Toddy left for a few hours undergoes fermentation with the help of naturally occurring yeast to form beverage containing about 6% alcohol. After 24 hours toddy becomes unpalatable. It can be now used for producing vinegar.

Probiotics. They are live bacteria and yeast that are taken as health drink to augment friendly gut flora, overcome pathogenic organisms and provide useful substances to the body. Probiotic flora includes *Lactobacillus* species, *Streptococcus thermophilus*, *Bacillus subtilis*, *Bifidobacterium bifidum* and *Saccharomyces boulardii*. Instead of taking these microbes directly, foods fermented by them are taken, e.g., Yogurt, Curd, Kefir, Coconut-Kefir, Raw Cheese, Tempeh, Sauerkraut, Natto (soyabeans fermented with *Bacillus subtilis*), etc.

II. Microbes in Industrial Products

Fermentative activity of microbes is used industrially to obtain a number of products. The two common ones are alcoholic fermentation and antibiotics.

Methodology. For any new industrial utilisation of a microbial activity, the technology passes through three stages—laboratory scale, pilot plant scale and manufacturing unit. The development from laboratory scale to manufacturing unit is called **scaling up**.

1. **Laboratory Scale.** Soon after the discovery of use of a microorganism, the maximum number of strains are searched and the most suitable strain is selected and multiplied. A laboratory scale apparatus/plant is manufactured. It has a glass fermentor (fermenter). All the parameters of the process are worked out like nutrients for the microbe, pH, aeration, disposal of CO₂ if evolved, optimum temperature, by products, product inhibition or stimulation, time of optimum production, separation of product and its purification. Ultimately, the laboratory scale process is finalised.

2. **Pilot Plant Scale.** It is intermediate stage where working of the laboratory scale process is tested, cost and quality of the product are evaluated. Glass vessels are replaced by metallic containers. The container where fermentation is carried out is called **bioreactor** or fermentor. Aeration system, pH corrections and temperature adjustments are perfected.

3. **Manufacturing Unit.** Its size is determined by the economics worked at during the pilot plant scale process. Bioreactor or fermentor is often large. Microorganisms are added in bioreactors in three ways : (i) Support growth system or on surface of nutrient medium. (ii) Suspended growth system or suspended in nutrient medium. (iii) Column or immobilised growth system where microorganisms placed in calcium alginate beads are kept in columns.

(A) Alcoholic Fermentation

Louis Pasteur found for the first time that beer and butter milk are produced due to activity of Yeast and Yeast-like microorganisms. Yeast species used in alcoholic fermentation are *Saccharomyces cerevisiae* (Brewer's Yeast), *S. ellipsoidens* (Wine Yeast), *S. sake* (Sake Yeast) and *S. pilsen* (Ginger Beer/Ale Yeast). The nutrient medium is barley malt for beer, fermented rye malt for gin, fermented rice for sake, cashew-apple for fenny, potato for vodka, fermented cereals for whisky, fermented molasses for rum and fermented juices for wines and brandy.

1. Yeast does not possess sufficient diastase/amylase. Therefore, either 1% malt or *Rhizopus* is used when the nutrient medium consists of complex carbohydrates as present in cereals and Potato. Hydrolysis of starch is carried out in separate tank at high temperature (55°C) for 30 minutes. The crushed food mixed with hot water for obtaining malt is called **mash**. The sweetened nutrient medium prior to alcoholic fermentation is called **wort**.

2. Bioreactor/fermentation tank is sterilised with the help of steam under pressure. The liquid nutrient medium or **wort** is added into the tank and sterilised similarly. It is then allowed to cool.

3. When the liquid nutrient medium is cooled down to appropriate temperature, it is inoculated with appropriate strain of Yeast through **support growth system** (on the surface) or **suspended growth system** (inside the wort). Fermentation occurs in three ways : (i) **Batch Process.** Bioreactor is very large (capacity upto 2,25,000 litres of medium). Yeast and nutrient are allowed to remain there till maximum alcohol content is achieved (6-12%). It is called **wash**. The same is removed and the tank sterilised for the next batch. (ii) **Continuous Process.** There is a regular removal of a portion of fermented liquor/wash and addition of more nutrient. (iii) **Fed Batch Process.** Nutrient is regularly fed in small quantities in the fermenter so as to optimise the working of the fermenting microbe without any inhibition. (iv) **Immobilised Yeast.** Lately Yeast is being used in immobilised state in calcium alginate beads. The technique is 20 times more efficient.

4. Both Beer and Wine are filtered, pasteurised and bottled without further distillation. Beer has an alcoholic content of 3 – 6% while in wines the alcoholic content is 9–12%. Higher alcoholic content is generally achieved through direct addition of alcohol. Hops are added to wort during preparation of beer. Distillation of the fermented broth is carried out in case of other alcoholic beverages called **hard liquors**, e.g., gin (40%), rum (40%), brandy (60–70%). **Rectified spirit** is 95% alcohol. **Absolute alcohol** is 100% alcohol.

5. Bye-products of alcoholic fermentation are CO_2 and Yeast. A number of other chemicals can be formed with the change of nutrient medium, pH and aeration – *n*-propanol, butanol, amyl alcohol, phenylethanol, glycerol, acetic acid, pyruvic acid, succinic acid, lactic acid, caproic acid, caprylic acid, ethyl acetate, acetaldehyde, diacetyl, hydrogen sulphide, etc.

(B) Antibiotics

The term was coined by Waksman (1942). **Antibiotics** (Gk. *anti*— against, *bios*—life) are chemical substances produced by some microbes which in small concentration can kill or retard the growth of harmful microbes without adversely affecting the host. **Penicillin** was the first antibiotic to be discovered by Alexander Fleming (1928). He found that fungus *Penicillium notatum* or its extract could inhibit the growth of bacterium *Staphylococcus aureus*. The antibiotic was however, commercially extracted by efforts of Chain and Florey. The chemical was extensively used in treating wounded American soldiers in world war II. Fleming, Chain and Florey were awarded Nobel Prize in 1945. Waksman and Woodruff isolated actinomycin in 1941 and streptothricin in 1942. Waksman and Albert (1943) and Waksman (1944) discovered streptomycin. Burkholder (1947) isolated chloromycetin.

Over 7000 antibiotics are known. Every year some 300 new antibiotics are discovered by means of **hypersensitive microorganisms** (started in 1970). *Streptomyces griseus* produces more than 41 antibiotics while *Bacillus subtilis* forms about 60 antibiotics. Antibiotics can be broad spectrum or specific. **Broad Spectrum Antibiotic**. It is an antibiotic which can kill or destroy a number of pathogens that belong to different groups with different structure and wall composition. **Specific Antibiotic**. It is an antibiotic which is effective only against one type of pathogens.

Types. There are five basic classes of antibiotics — betalactams, amino-glycosides, quinolones, sulphonamides and glycopeptides.

Action. Antibiotics function either as **bactericides** (killing bacteria) or **bacteriostatic** (inhibiting growth of bacteria). This is done by (i) Disruption of wall synthesis, e.g., penicillin, cephalosporins, bacitracin. (ii) Disruption of plasmalemma repair and synthesis, e.g., polymyxin, nystatin, amphotericin. (iii) Inhibition of 50 S ribosome function, e.g., erythromycin. (iv) inhibition of 30 S ribosome function, e.g., streptomycin, neomycin. (v) Inhibition of aa-tRNA binding to ribosome, e.g., tetracycline. (vi) Inhibition of translation, e.g., chloramphenicol.

Characteristics of a Good Antibiotic. (a) Harmless to host with no side effect. (b) Harmless to normal microflora of alimentary canal. (c) Ability to destroy pathogen as well as broad spectrum. (d) Effective against all strains of pathogen. (e) Quick action.

Limitations. Antibiotics are not effective against all pathogens. They have little effect against viruses. Most antibiotics are useful against one or a few diseases. Their excess or deficient use is dangerous. Therefore, antibiotics should be taken only in dose prescribed by a physician, not on the suggestion of a friend, pharmacist or chemist. Self medication and prophylactic use should be avoided.

Resistance to Antibiotics. Pathogens often develop resistance to existing antibiotics so that newer antibiotics are required to be produced. The resistance is generally produced due

to extrachromosomal genes present in plasmids. They can pass from one bacterium to another due to transformation and transduction. As a result of repeated transformation, certain strains of bacteria have become multiresistant or **super bugs**, e.g., NDM-1. Resistance to antibiotics comes from (i) Development of copious mucilage. (ii) Alteration of cell membrane so that antibiotic cannot recognise the pathogen. (iii) Alteration of cell membrane which prevents antibiotic entry. (iv) Change to L-form by pathogen. (v) Mutation in pathogen. (vi) Development of pathogen enzyme capable of modifying antibiotic.

Production of Antibiotic. Suitable strain of microorganism is cultivated on a sterilised nutrient medium provided with optimum pH, aeration, temperature, antifoaming agent and antibiotic precursor (if any). When sufficient antibiotic has diffused into medium, the microorganism is separated and the antibiotic is extracted from medium by precipitation, absorption or solvent treatment. It is purified, concentrated and bioassayed before packing.

Antibiotics are obtained from lichens, fungi, eubacteria and actinomycetes. The common antibiotic from lichens is usnic acid (*Usnea* and *Cladonia*). Amongst eubacteria, two account for most antibiotics, *Bacillus* (70%) and *Pseudomonas* (30%). Fungi yield a number of antibiotics like penicillin, patulin and griseofulvin (*Penicillium* species), cephalosporins (from marine fungus *Cephalosporium acremonium*), antiameobin (*Emericellopsis*), polyporin (*Polystictus sanguineus*), clitocybin (*Clitocybine gigantea*), citrinin (*Aspergillus clavatus*, *Penicillium citrinum*), clavacin (*Aspergillus clavatus*), etc. Most famous drugs are got from actinomycetes, especially *Streptomyces*, e.g., streptomycin, chloramphenicol, tetracyclin, terramycin, erythromycin. Other antibiotic yielding actinomycetes are *Streptosporangium*, *Streptoverticillium*, *Micromonospora*, *Nocardia* and *Actinoplanes*, etc. Some antibiotics are modified to enhance their potential. They are semisynthetic, e.g., ampicillin, oxocillin.

Antibiotic	Source	Action
Penicillin	<i>Penicillium chrysogenum</i> , <i>P. notatum</i> + Phenyl Acetic Acid.	Tonsillitis, Sore Throat, Gonorrhoea, Rheumatic Fever, some Pneumonia types.
Griseofulvin	<i>Penicillium griseofulvum</i>	Antifungal, especially for Ringworm.
Nystatin	<i>Streptomyces noursei</i>	Antifungal for Candidiasis and overgrowth of Intestinal Fungi during excessive antibiotic treatment.
Neomycin	<i>Streptomyces fradiae</i>	Antibacterial against Gram negative bacilli and some Gram (+) bacteria.
Viridin	<i>Gliocladium virëns</i>	Antifungal.
Hamycin	<i>Streptomyces pimprei</i>	Antifungal for Thrush.
Fumagillin	<i>Aspergillus fumigatus</i>	Broad spectrum antibacterial especially against <i>Salmonella</i> and <i>Shigella</i> .
Bacitracin	<i>Bacillus licheniformis</i>	Syphilis, Lymphonema or Reticulosis.
Streptomycin	<i>Streptomyces griseus</i>	Meningitis, Pneumonia, Tuberculosis and Local Infections. Toxic in some through eighth cranial nerve.
Chloramphenicol/ Chloromycetin	<i>Streptomyces venezuelae</i> , <i>S. lavendulae</i> , Now synthetic	Typhoid, Typhus, Whooping Cough, Atypical Pneumonia, Bacterial Urinary Infections.
Tetracyclines/ Aureomycin	<i>Streptomyces aureofaciens</i>	Viral Pneumonia, Osteomyelitis,
Oxytetracycline/ Terramycin	Chlorotetracycline → Hydrogenation <i>Streptomyces rimosus</i>	Whooping Cough, Eye Infections.
Erythromycin	<i>Streptomyces erythreus</i> (= <i>S. erythraeus</i>)	Intestinal and Urinary Infections (Spirochaetes, Rickettsiae, Viruses)
Gentamycin	<i>Micromonospora purpurea</i>	Typhoid, Common Pneumonia, Diphtheria, Whooping Cough, etc.
Polymixin	<i>Bacillus polymyxa</i>	Effective against Gram (+) bacteria Antifungal.

Uses. Antibiotics are used (i) As medicines for treatment of a number of pathogenic or infectious diseases. Because of antibiotics and their newer more potent forms, a number of formidable diseases are now curable, e.g., plague, typhoid, tuberculosis, whooping cough, diphtheria, leprosy, etc. (ii) As preservatives in perishable fresh food articles (e.g., meat and fish), pasteurised and canned foods. (iii) As feed supplement for animals, especially poultry birds because they enhance growth.

Judicious Use. Antibiotic should be used judiciously in appropriate dose for a particular duration on the prescription of a physician, preferably after due laboratory test. However, for obtaining quick relief, antibiotics are being over-used. A major area of over use is taking in of antibiotics in viral infections. Another reason is self medication, prophylactic use, lack of proper test, incorrect use as per weight, change of antibiotics midway of treatment and consulting two or more physicians simultaneously.

Insufficient dosage of antibiotics is also a cause of several complications and development of resistance which is not only risky to the patient but also other people. Therefore, it is important that everybody should be made aware of common diseases, role of antibiotics, their use and dangers of insufficient or over-use, avoidance of quacks and undergo tests when required.

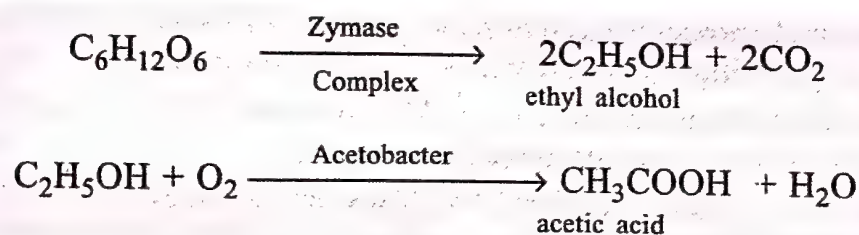
(C) Chemicals, Enzymes and Other Bioactive Molecules

Microbes are being used for commercial and industrial production of certain chemicals like organic acids, alcohols, enzymes and other bioactive molecules. **Bioactive molecules** are those molecules which are functional in living systems or can interact with their components. A number of them are obtained from microbes.

Organic Acids

A number of organic acids are being manufactured with the help of microbes. The important ones are as follows:

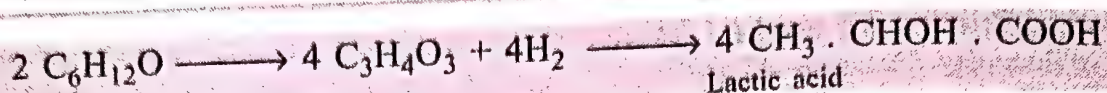
1. **Acetic Acid.** It is prepared from fermented alcohols with the help of acetic acid bacteria, *Acetobacter aceti*. Alcoholic fermentation is anaerobic process, but the conversion of alcohol to acetic acid is aerobic one.



As soon as 10–13% acetic acid is formed, the liquid is filtered. It is used after ripening as vinegar. The type and quality of vinegar depends upon substrate used for alcoholic fermentation and ripening. For other purposes, acetic acid is purified. The organic acid is employed in pharmaceuticals, colouring agents, insecticides, plastics, etc.

2. **Citric Acid.** It is obtained through the fermentation carried out by *Aspergillus niger* and *Mucor* species on sugary syrups. Yeast *Candida lipolytica* can also be employed, provided its nutrient medium is made deficient of iron and manganese. Citric acid is employed in dyeing, engraving, medicines, inks, flavouring and preservation of food and candies.

3. **Lactic Acid.** It was the first organic acid to be produced from the microbial fermentation in starchy and sugary medium. Lactic acid fermentation is carried out by both bacteria (e.g., *Streptococcus lactis*, *Lactobacillus* species) and fungi (e.g., *Rhizopus*). The acid derived from fungal sources is costlier but is of high purity. Any starchy or sugary medium is used.



Lactic acid is used in confectionery, fruit juices, essences, pickles, curing of meat, lemonades, canned vegetables and fish products. It is also employed as mordant in tanning, printing of wool in the preparation of plastics and pharmaceuticals.

4. **Gluconic Acid.** The acid is prepared by the activity of *Aspergillus niger* and *Penicillium* species. Calcium gluconate is used widely as a source of calcium for infant, cows and lactating mothers. It is also used in preparation of pharmaceuticals.

5. **Butyric Acid.** The acid is produced during fermentation activity of bacterium *Clostridium acetobutylicum*. Rincidity of butter is also due to its formation.

6. **Alcohols.** Ethanol, methanol, propanol and butanol are alcohols that can be produced commercially by fermentation activity of some fungi (e.g., Yeast, *Mucor*, *Rhizopus*) and bacteria (e.g., *Clostridium acetobutylicum*, *C. saccharotobutylicum*). The alcohols are important industrial solvents.

Enzymes

Enzymes are proteinaceous substances of biological origin which are capable of catalysing biochemical reactions without themselves undergoing any change. The word **enzyme** was coined by William Kuhne (1867) after the fact the yeast provided the most well studied biocatalytically controlled reactions of alcoholic fermentation (Gk. *en-* in, *zyme-* yeast). Buchner (1901) found yeast extract to have enzymatic activity. The number of enzymes now runs into several thousands. All of them are macromolecules (large sized molecules) with a specific three-dimensional shape. Enzymes are substrate specific and carry out a specific catalytic action. They work best at room temperature and near-neutral pH with the exception of several digestive enzymes. Use of enzymes in biotechnology had a number of problems which have been largely overcome by the technique of immobilisation of enzymes inside artificial cells or gels. About 300 enzymes are being used in industry and medicines. Most of them are obtained from microbes.

1. **Proteases.** They are enzymes that degrade proteins and polypeptides. Proteases are obtained from *Mortierella renispora*, *Aspergillus* and *Bacillus* species. The enzymes are used in (i) Clearing (Chill proofing) beer and whisky. (ii) Cleaning of hides. (iii) Softening of bread and meat. (iv) Degumming of silk. (v) Manufacture of liquid glue. (iv) Manufacture of detergents capable of removing proteinaceous stains.

2. **Amylases.** They degrade starches. Amylases are obtained from *Aspergillus*, *Rhizopus* and *Bacillus* species. The enzymes are employed for (i) Softening and sweetening of bread. (ii) Production of alcoholic beverages (e.g., beer, whisky) from starchy materials. (iii) Clearing of turbidity in juices caused by starch. (iv) Separation and desizing of textile fibres.

Amylase, glucoamylases and glucoisomerases are employed in conversion of corn starch into fructose rich corn syrup. Incidentally fructose is the sweetest of the sugars. Therefore, corn syrup is sweeter than sucrose solution. It is used in sweetening and flavouring soft drinks, biscuits, cakes, etc.

3. **Rennet.** It is an extract from the stomach of calf that contains enzyme rennin. Rennet or chymosin is now being obtained from *Mucor* and *Endothio* species. *Withania* and fig (ficin) also yield similar product.

4. **Lactases.** They are obtained from *Saccharomyces fragilis* and *Torula cremoris*. The enzymes convert lactose (milk sugar) into lactic acid. Lactic acid can coagulate milk protein, casein. Lactases prevent crystals formation (sandiness) in dairy preparations like ice-cream and processed cheese.

5. **Streptokinase** (Tissue Plasminogen Activator or TPA). It is an enzyme obtained from the cultures of some haemolytic bacterium *Streptococcus* and modified genetically to function as **clot buster**. It has fibrinolytic effect. Therefore, it helps in clearing blood clots inside the blood vessels through dissolution of intravascular fibrin.

6. **Pectinases**. They are obtained commercially from *Byssoschlamys fulvo*. Alongwith proteases, they are used in clearing of fruit juices. Other uses are in retting of fibres and preparation of green coffee.

7. **Lipases**. They are lipid dissolving enzymes that are obtained from *Candida lipolytica* and *Geotrichum candidum*. Lipases are added in detergents for removing oily stains from laundry. They are also used in flavouring cheese.

Cyclosporin A

It is an eleven membered cyclic oligopeptide obtained through fermentative activity of fungus *Trichoderma polysporum*. It has antifungal, anti-inflammatory and immunosuppressive properties. It inhibits activation of T-cells and therefore, prevents rejection reactions in organ transplantation.

Statins

They are products of fermentation activity of yeast *Monascus purpureus* which resemble mevalovate and are competitive inhibitors of β -hydroxy- β -methylglutaryl or HMG CoA reductase. This inhibits cholesterol synthesis. Statins are, therefore, used in lowering blood cholesterol, e.g., lovastatin, pravastatin, simvastatin.

III. Microbes in Sewage Treatment

Sewage or municipal waste should not be directly passed into rivers, streams and other water bodies because it not only contains human excreta and other organic wastes but a number of pathogenic microbes. It is made less polluting by passing it through **sewage treatment plants (STPs)**. Here heterotrophic microbes naturally present in sewage carry out the process of decomposition. There are three stages of this treatment; primary, secondary and tertiary. Primary treatment is physical, secondary biological and tertiary chemical. Waste water can be passed into rivers after secondary treatment.

Primary or Physical Treatment. It is the process of removal of small and large, floating and suspended solids from sewage through two processes of filtration and sedimentation. First floating and suspended matter is removed through sequential filtration with progressively smaller pore filters. The filtrate is then kept in large open settling tanks where grit (sand, silt, small pebbles) settles down. Aluminium or iron sulphate is added in certain places for flocculation

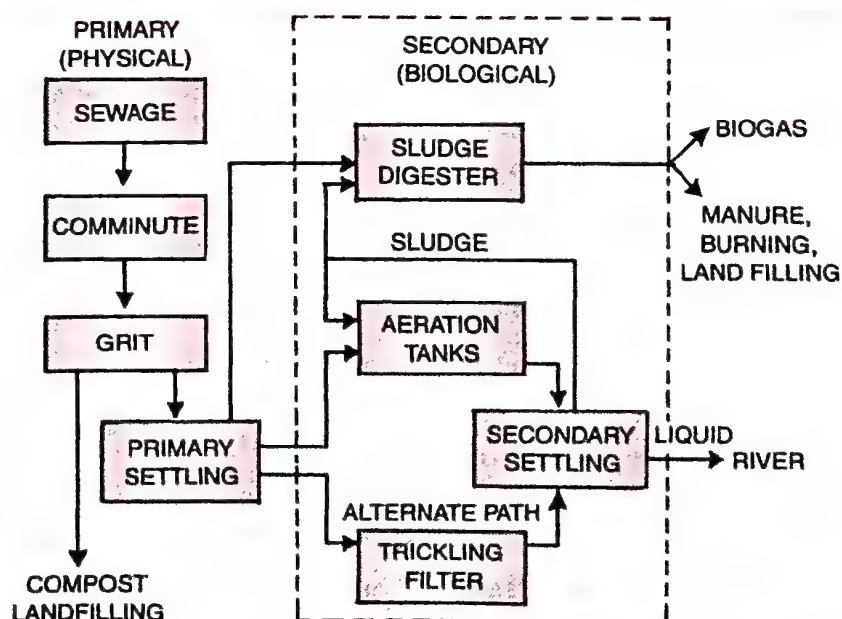


Fig. 10.4. Flow chart of sewage treatment.

and settling down of solids. The sediment is called **primary sludge** while the supernatant is called **effluent**. The primary sludge traps a lot of microbes and debris. It is subjected to composting, land fill or anaerobic digestion to produce biogas and manure.

Secondary or Biological Treatment. There are several methods of secondary treatment, e.g., oxidation tanks, trickling filter system and activated sludge system. In activated sludge system, the primary effluent is taken to **aeration tanks**. Liquid is constantly agitated mechanically. Air is also pumped into it. Some activated sludge of the previous operation is inoculated to hasten decomposition. A large number of aerobic heterotrophic microbes grow in the aeration tank. They include bacteria of different types, some filamentous fungi, yeasts and protozoan. They form flocs. **Flocs** are masses of bacteria held together by slime and fungal filaments to form mesh like structures. The microbes digest a lot of organic matter, converting it into microbial biomass and releasing a lot of minerals. This reduces **Biochemical Oxygen Demand** or **BOD**. As the BOD of the waste matter is reduced to 10–15% of raw sewage, it is passed into **settling tank**. In settling tank, the bacterial flocs are allowed to undergo sedimentation. The effluent or supernatant is generally passed into natural waters like rivers and streams. It can also be treated chemically to further purify it.

The sediment of settling tank is called **activated sludge**. A part of it is used as inoculum in aeration tanks. The remaining is passed into a large tank called **anaerobic sludge digester**. They are designed for continuous operation. The aerobic microbes present in the sludge get killed. Anaerobic microbes digest the organic mass as well as aerobic microbes (bacteria and fungi) of the sludge. They are of two types, nonmethanogenic and methanogenic. Methanogenic bacteria produce **marsh gas** which is a mixture of gases containing methane, H_2S and CO_2 . The mixture also called **biogas** is inflammable and is a source of energy. The spent sludge can be used as manure or part of compost.

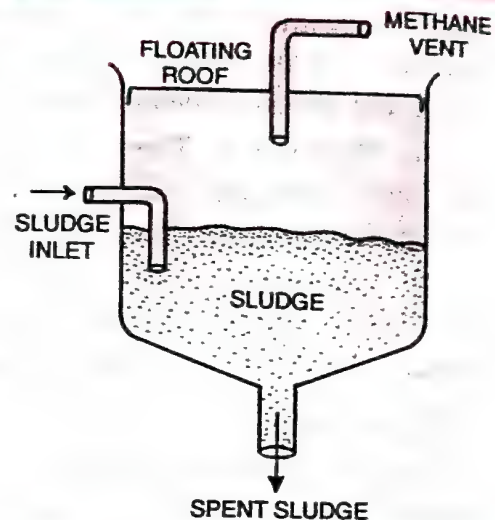


Fig. 10.5. Anaerobic sludge digester.

Differences Between Primary Sludge and Activated Sludge

Primary Sludge	Activated Sludge
1. It is sludge formed during primary sewage treatment.	1. It is sludge formed during secondary sewage treatment.
2. It does not possess flocs of decomposer microbes.	2. It possess flocs of decomposer microbes.
3. It does not require aeration.	3. Formation of activated sludge requires aeration.
4. Little decomposition has occurred during formation of primary sludge.	4. A lot of decomposition has occurred during formation of activated sludge.

River Action Plans. The technology for sewage treatment is more than century old. However, urbanisation has been very rapid during this period. Currently, each country is producing several million gallons of waste water everyday. However, the number of sewage treatment plants has not increased correspondingly. The result is that untreated sewage is

being discharged directly into rivers and other water bodies causing pollution and increased incidence of water borne diseases. In order to protect the major rivers of India from sewage pollution, the Ministry of Environment and Forests, has initiated development of sewage treatment plants under the National River Conservation Authority, e.g., Ganga Action Plan (GAP), Yamuna Action Plan, Sutlej Action Plan, Gomti Action Plan.

IV. Microbes in Production of Biogas (Gobar Gas)

Biogas is a methane rich fuel gas produced by anaerobic breakdown or digestion of biomass with the help of methanogenic bacteria. Biogas is made up of methane (50–70%), carbon dioxide (30–40%) with traces of nitrogen, hydrogen sulphide and hydrogen. 50% of the combustible energy present in the organic waste can be changed into methane gas. The energy realised from biogas depends upon the proportion of methane present in it. The calorific value of biogas is 23–28 MJ/m³. The effluent and residue left after the fermentative generation of biogas is rich in minerals, lignin and a part of cellulose. It is an ideal manure. Biogas or gobar gas generation has been taken up in India on a large scale. Already, there are over a million individual and several thousand community biogas plants operating in the country. The technology was developed by the collaboration of Khadi and Village Industries Commission (KVIC) and Indian Agricultural Research Institute (IARI).

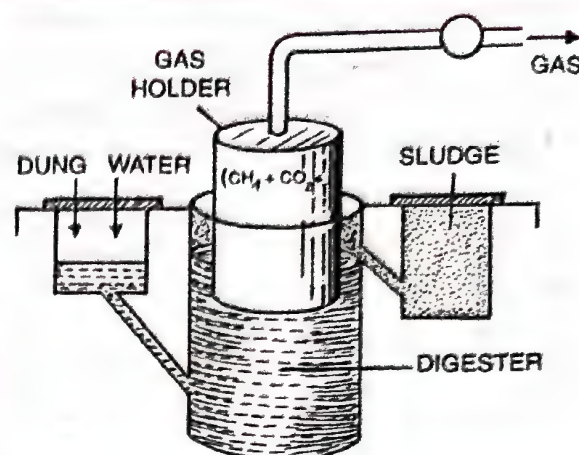


Fig. 10.6. A biogas plant.

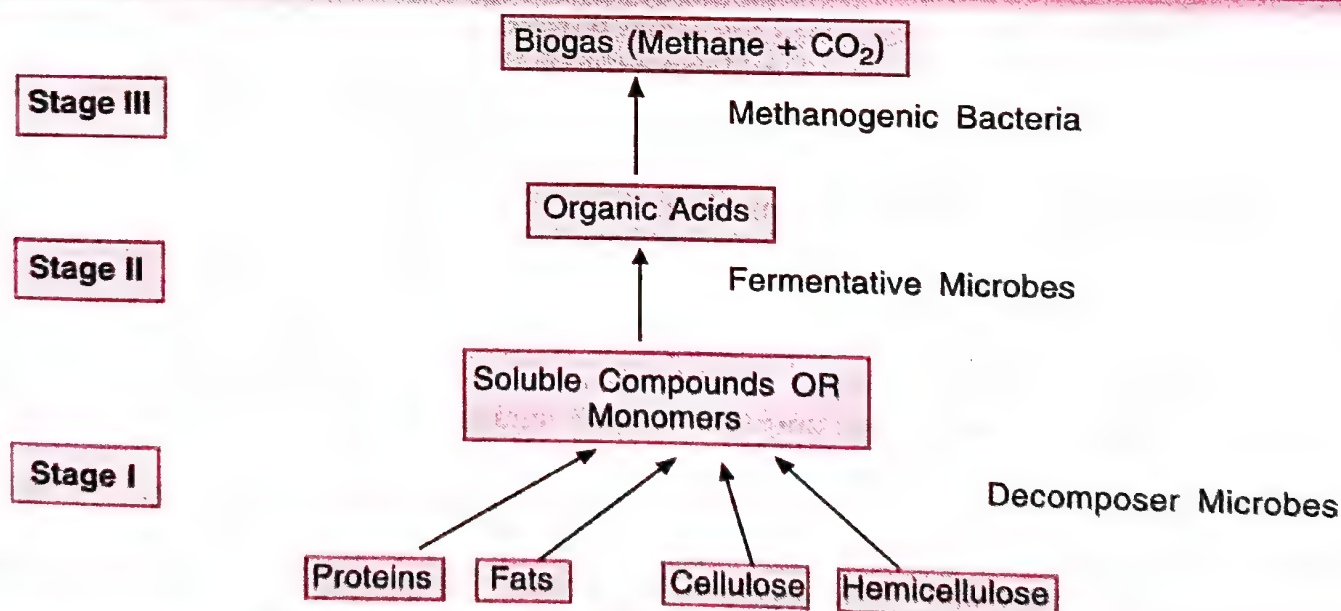


Fig.10.7. Stages in Anaerobic Digestion during biogas formation.

Biogas generation is a three-stage anaerobic digestion of animal and other organic wastes. The latter consist of lignin, cellulose, hemicellulose, lipids and proteins. Lignin cannot be broken down under anaerobic conditions. Cellulose digestion is slower than that of other substances.

(i) **Solubilisation.** In the first stage of anaerobic digestion, facultative anaerobic decomposer microbes (e.g., *Clostridium*, *Pseudomonas*) bring about enzymatic breakdown of complex organic compounds into simpler and soluble compounds often called 'monomers'.

For this, the decomposer microbes secrete cellulases, proteases and lipases (cellulolytic, proteolytic and lipolytic enzymes).

(ii) **Acidogenesis.** In the second stage, the simple soluble compounds of microbial digestion or monomers are acted upon by fermentation causing microbes (*e.g.*, *Acetovibrio*, *Propionibacterium*). The latter change the monomers into organic acids.

(iii) **Methanogenesis.** In the third stage, organic acids, especially acetic acid, are acted upon by **methanogenic bacteria**. The methane bacteria convert organic acids as well as carbon dioxide into methane. The biogas thus formed is stored in tanks for supply.

Advantages. Using organic wastes first for biogas generation has several advantages over their direct use as fuel or fertilizer (Fig. 10.8).

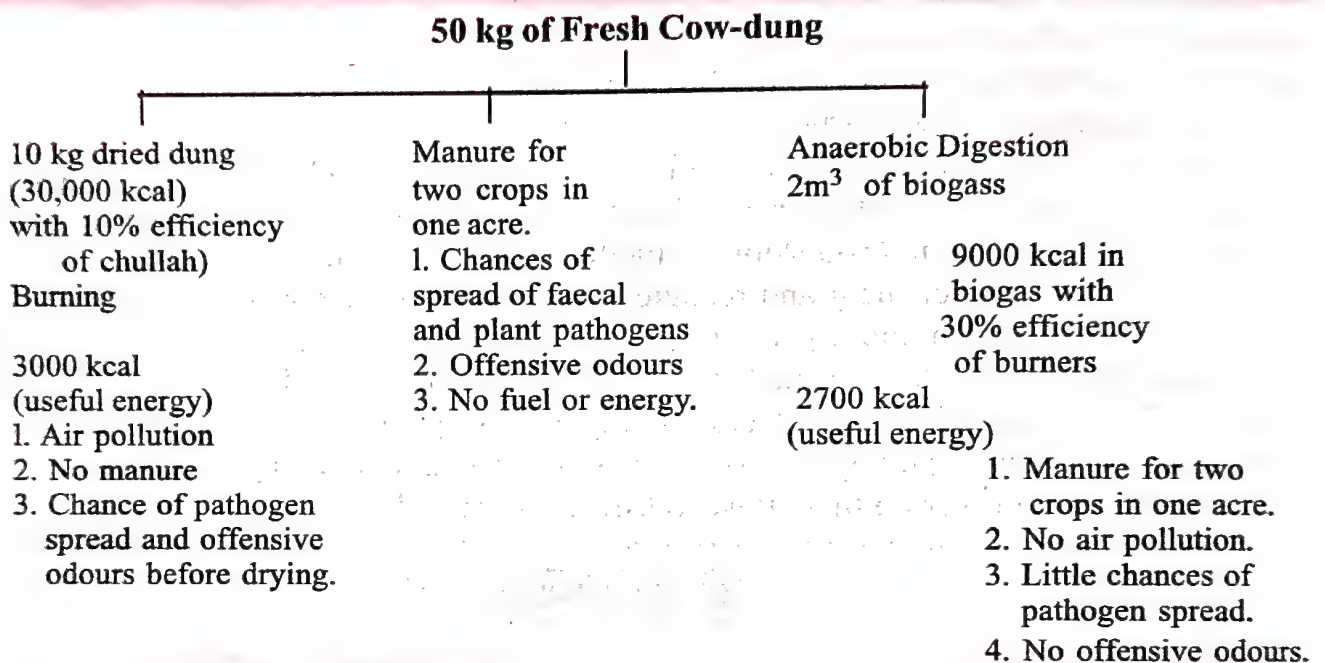


Fig. 10.8. Alternate ways of using cow-dung.

- (1) It provides both energy and manure.
- (2) Biogas is a storable form of energy which can be used more efficiently and economically.
- (3) Biogas has wider applications than the direct burning of organic wastes.
- (4) The energy value of biogas is lower than that of organic matter but due to more efficient handling, the net energy output is roughly equal to the output in direct burning of organic wastes.
- (5) It minimises the chances of spread of faecal pathogens. Sanitation and health are, therefore, improved. This is not possible in other cases.
- (6) The fertilizer value of the manure produced in biogas plants is similar to that of manure formed directly from organic wastes.
- (7) Spread of plant pathogens with the help of crop residue is checked.
- (8) Biogas use does not add to pollution.

V. Microbes as Biocontrol Agents

Right from preparation of land for cultivation, sowing and reaping to storage of plant produce, the agriculture is threatened by pathogens and pests. Therefore, crop plants have to be given protection by killing or removing pathogens and pests. This has been carried out through the use of chemical pesticides. Chemical pesticides decrease the growth of weeds,

reduce attack from pathogens and drive away or kill insects, worms and birds which happen to feed on crop plants. It is estimated that despite our best efforts and use of chemical pesticides, 30% of the produce is lost to pathogens and pests due to reason that the latter continue to develop resistance against them. Further the chemical pesticides are toxic and biocides. They kill even useful organisms, harm human beings and animals, pollute soil and water, fruits, vegetables and crop plants.

Therefore, instead of trying to eradicate pests and pathogens through chemicals, it is better to use biological agents for controlling them. Here pests and pathogens are not eradicated but kept at manageable levels by a system of checks and balances as operating in ecosystem. An organic gardener holds the view that eradication of pests is undesirable because without them the beneficial predatory and parasitic organisms which depend upon them for food would also be annihilated. The natural method of pest and pathogen control involving use of viruses, bacteria and other insects (which are their natural predators and pests) is called **biocontrol** or **biological control**. For example, Lady bird Beetle (Beetle with red and black markings) feeds on aphids while Dragonflies prey upon Mosquitoes. Free living fungus *Trichoderma* found in root ecosystem, exerts biocontrol over several plant pathogens. Nonpathogenic *Agrobacterium radiobacter* protects the plants from crown gall disease caused by *Agrobacterium tumefaciens*. Baculoviruses (mostly of genus *Nudeopolyhedrovirus*) are useful in controlling many insects and other arthropods. They are species specific narrow spectrum bioinsecticides. There is no side effect on plants, mammals, birds, fish and non-target insects. Beneficial insects are conserved. Baculoviruses are, therefore, an important component of **integrated pest management (IPM) programme** and is dealing with ecological sensitive areas.

Biopesticides

Biopesticides are those biological agents that are used for control of weeds, insects and pathogens. The micro-organisms used as biopesticides are viruses, bacteria, protozoa, fungi and mites. Some of the biopesticides are being used on a commercial scale. Most important example is the soil bacterium, *Bacillus thuringiensis* (*Bt*). Spores of this bacterium possess the insecticidal Cry protein. Therefore, spores of this bacterium kill larvae of certain insects. The commercial preparations of *B. thuringiensis* contain a mixture of spores, Cry protein and an inert carrier. This bacterium was the first biopesticide to be used on a commercial scale in the world, and is the first biopesticide being produced on a commercial scale in India.

Biopesticides are of two types: bioherbicides and bioinsecticides.

(i) **Bioherbicides.** Herbicides are chemicals that are used for inhibiting the growth of plants in unwanted places. Herbicides used for controlling weeds in the cultivated areas are called weedicides. A number of risks are involved in the use of chemical herbicides. This can be avoided if herbicide resistance can be introduced in the crop plants. It is possible through genetic engineering or recombinant DNA technology. Transgenic Tomato and Tobacco plants have been developed which show tolerance to specific herbicides.

Certain crop plants do not allow the weeds to grow nearby. They are called **smoother crops**, e.g., Barley, Rye, Sorghum, Millet, Sweet clover, Alfalfa, Soybean, Sunflower. Smoother crops eliminate weeds through chemicals. Crop rotation with these crops will naturally reduce the incidence of weeds.

Another way of weed control is the introduction of specific insects which feed on the weeds. Extensive growth of *Opuntia* in India and Australia was checked through the introduction of its natural herbivore, cochineal insect (*Cactoblastis cactorum*). Similarly, growth of *Hypericum perforatum* or Klamath weed was checked by U.S.A. through the introduction of *Chrysolina* beetles.

An organism which controls or destroys unwanted plant growth without harming the useful plant is called bioherbicide. The first bioherbicide happened to be **mycoherbicide**. It was put to use in 1981. The herbicide is *Phytophthora palmivora*. The fungus does not allow the Milkweed Vine to grow in *Citrus* orchards. Growth of *Eichhornia crassipes* (Water Hyacinth) is being controlled by *Cercospora rodmanii* in USA and *Alternaria eichhorniae* in India. *Puccinia chondrilla* has controlled the growth of skeleton weed, *Chondrilla juncea* in Australia. Fungal spores are now available to be sprayed over weeds for their elimination. Two of them are 'Devine' and 'Collego'. The spores are ideal for marketing because they can tolerate adverse conditions and can remain viable for long periods.

(ii) **Bioinsecticides**. Bioinsecticides are those biological agents that are used to control harmful insects. They include the following.

(a) **Predators**. Destructive insects or plant pests can be brought under control through introduction of their natural predators. The predators should be specific and unable to harm the useful insects. Introduction of ladybugs (Lady Bird Beetles) and Praying Mantis has been successful in combating scale insects or aphids which feed on plant sap.

(b) **Parasites and Pathogens**. This is alternate biological control of plant pests through the search of their natural parasites and pathogens. They include viruses, bacteria, fungi and insect parasitoids. **Parasitoids** are organisms that live as parasites for some time (as early or larval stage) and free living at other times, e.g., *Trichogramma*. Nucleopolyhedrovirus (NPV) are species specific. For example, *Baculovirus heliothis* (a virus) can control Cotton bollworm (*Heliothis Zea*). Similarly, *Bacillus thuringensis* (a bacterium) is effective against the cabbage looper (*Trichoplusiani*) and *Entomophthora ignobilis* (a fungus) the green peach aphid of Potato (*Myzus persicae*). In U.S.S.R. the fungus *Beauveria bassiana* has been successfully employed in controlling Potato beetle and Codling moth. Parasitoids of *Encarsia* have been used in controlling whitefly in many countries.

(c) **Natural Insecticides**. They are insecticides and related pesticides which are obtained from microbes and plants. A number of natural insecticides are available. The common ones include (i) **Azadirachtin** from Margosa or Neem (*Azadirachta indica*). It occurs in Margosa extract. Spray of the same keeps away the Japanese beetles and other leaf eating pests because of the antifeedant property of azadirachtin. (ii) **Rotenones**. They are powerful insecticides which are harmless to warm blooded animals. Chinese are believed to be first to discover their insecticidal properties. Rotenones are obtained from the roots of *Derris elliptica* and *Lonchocarpus nicou*. (iii) **Squill**. The red variety of Sea Onion (Red Squill, *Uregrina maritima*) produces a radicide which does not have any harmful effect on other animals. (iv) **Nicotine**. It is obtained from *Nicotiana* species. The purified chemical is highly poisonous. Nicotine sulphate is one of the most toxic insecticides. (v) **Pyrethrum**. It is an insecticide which is obtained from the inflorescence of *Chrysanthemum cinerarifolium* (Dalmation Pyrethrum), *C. coccineum* and *C. marshallii*. The active compounds are pyrethrin and cinerin. Pyrethrin is also used in fly sprays, aerosols, mosquito coils, etc. (vi) **Thurioside**. It is a toxin produced by bacterium *Bacillus thuringensis*. The toxin is highly effective against different groups of insects like moths, flies, mosquitoes and beetles. It does not cause any adverse environmental pollution or disturbance. Thurioside occurs as crystals in the bacterium. It kills the susceptible insects through inhibiting ion transport in the midgut, formation of pores in gut epithelium, swelling and bursting of cells. (vii) **Transgenic Plants**. They are crop plants which are modified through genetic engineering to develop natural resistance to insects by inserting *cry* genes of *Bacillus thuringensis* into them, e.g., Bt Cotton. Similarly, transgenic Tomato has been developed which is resistant to hornworm larvae.

Differences Between Chemical Pesticides and Biopesticides

Chemical Pesticides	Biopesticides
<ol style="list-style-type: none"> 1. They are synthetic pesticides. 2. They are broadspectrum and affect several nontarget organisms. 3. Chemical pesticides pollute air, water and soil. 	<ol style="list-style-type: none"> 1. They are live organisms or their natural products having pesticidal properties. 2. They are pest specific and are harmless to other organisms. 3. Biopesticides are nonpollutant.

VI. Microbes As Biofertilisers

Chemical fertilizers are being used in increasing amounts in order to increase output in high yielding varieties of crop plants. However, chemical fertilizers cause pollution of water bodies as well as ground water, besides getting stored in crop plants. Therefore, environmentalists are pressing for switch over to organic farming. Organic farming is the raising of unpolluted crops through the use of manures, bifertilizers and biopesticides that provide optimum nutrients to crop plants, keeping pests and pathogens under control.

Biofertilizers are micro-organisms which bring about nutrient enrichment of soil by enhancing the availability of nutrients to crops. The micro-organisms which act as biofertilizers are bacteria, cyanobacteria (blue green algae) and mycorrhizal fungi. Bacteria and cyanobacteria have the property of nitrogen fixation while mycorrhizal fungi preferentially withdraw minerals from organic matter for the plant with which they are associated. Nitrogen fixation is the process of conversion of molecular or dinitrogen into nitrogen compounds. Insoluble forms of soil phosphorus are converted into soluble forms by certain micro-organisms. This makes the phosphorus available to the plants. Phosphate is also solubilised by some bacteria and by some fungi that form association with plant roots. The various biofertilizers are as follows.

(i) **Free Living Nitrogen Fixing Bacteria.** They live freely in the soil and perform nitrogen fixation. Some of them are saprotrophic, living on organic remains, *e.g.*, *Azotobacter*, *Bacillus polymyxa*, *Clostridium*, *Beijerinckia*. They are further distinguished into aerobic and anaerobic forms. The property of nitrogen fixation is also found in photoautotrophic bacteria, *e.g.*, *Rhodospseudomonas*, *Rhodospirillum*, *Chromatium*. Inoculation of soil with these bacteria helps in increasing yield and saving of nitrogen fertilizers. For example, *Azotobacter* occurring in fields of Cotton, Maize, Jowar and Rice, not only increases yield but also saves nitrogen fertilizer to the tune of 10–25 kg/ha. Its inoculation is available under the trade name of **azotobactrin**.

(ii) **Free Living Nitrogen Fixing Cyanobacteria.** A number of free living cyanobacteria or blue-green algae have the property of nitrogen fixation, *e.g.*, *Anabaena*, *Nostoc*, *Aulosira*, *Totipotrix*, *Cylindrospermum*, *Stigonema*. Cyanobacteria are photosynthetic. Therefore, they add organic matter as well as extra nitrogen to the soil. *Aulosira fertilissima* is considered to be the most active nitrogen fixer of Rice fields in India (Aiyer *et al*, 1972). *Cylindrospermum licheniforme* grows in Sugarcane and Maize fields. Cyanobacteria are an extremely low cost biofertilisers. In Tamil Nadu, the technique of cyanobacteria inoculation to rice fields is being followed. Phosphate, Molybdenum and Potassium are supplied additionally.

(iii) **Loose Association of Nitrogen Fixing Bacteria.** Certain nitrogen fixing bacteria like *Azospirillum* live around the roots of higher plants without developing any intimate

relationship. It is often called **rhizosphere association**. The bacteria obtain some plant exudate and use the same as part of their food requirement. The bacteria fix nitrogen and exude a part of the fixed nitrogen for use by the plant. The phenomenon is termed as **associative mutualism** (= associative symbiosis).

(iv) **Symbiotic Nitrogen Fixing Bacteria**. They form a mutually beneficial association with the plants. The bacteria obtain food and shelter from plants. In return, they give a part of their fixed nitrogen to the plants. The most important of the symbiotic nitrogen fixing bacteria is *Rhizobium* (pl *Rhizobia*). It forms nodules on the roots of legume plants. There are about a dozen species of *Rhizobium* which form association with different legume roots, e.g., *R. leguminosarum*, *R. lupini*, *R. trifolii*, *R. meliloti*, *R. phaseoli*. These bacteria, also called rhizobia, live freely in the soil but cannot fix nitrogen except for a strain of Cowpea *Rhizobium* (Mc Comb *et al*, 1975). They develop the ability to fix nitrogen only when they are present inside the root nodules. In the nodule cells, bacteria (bacteroids) lie in groups surrounded by membrane of the host which is lined by a pink-red pigment called **leghaemoglobin**. Presently cultures of *Rhizobium* specific for different crops are raised in the laboratory.

Frankia, a nitrogen fixing mycelial bacterium (actinomycete), is associated symbiotically with the root nodules of several nonlegume plants like *Casuarina*, *Alnus* (Alder) *Myrica*, *Rubus* etc. Leaves of a few plants (e.g., *Ardisia*) develop special internal cavities for providing space to symbiotic nitrogen fixing bacteria, *Xanthomonas* and *Mycobacterium*. Such leaves are a constant source of nitrogen fertilizer to the soil.

(v) **Symbiotic Nitrogen Fixing Cyanobacteria**. Nitrogen fixing cyanobacteria (blue-green algae) form symbiotic association with several plants, e.g., cycad roots, lichens, liverworts, *Azolla* (fern). Out of these, *Azolla-Anabaena* association is of great importance to agriculture. *Azolla pinnata* is a small free floating fresh water fern which multiplies rapidly, doubling every 5–7 days. The fern can coexist with rice plants because it does not interfere with their growth. In some South-East Asian countries, especially China, the rice fields are regularly provided with *Azolla*.

Anabaena azollae resides in the leaf cavities of the fern. It fixes nitrogen. A part of the fixed nitrogen is excreted in the cavities and becomes available to the fern. The decaying fern plants release the same for utilization of the rice plants. When field is dried at the time of harvesting, the fern functions as the green manure, decomposing and enriching the field for the next crop.

(vi) **Microphos Biofertilizers**. They release phosphate from bound and insoluble states, e.g., *Bacillus polymyxa*, *Pseudomonas striata*, *Aspergillus species*.

(vii) **Mycorrhiza** (pl-Mycorrhizae Frank, 1885). It is a mutually beneficial or symbiotic association of a fungus with the root of a higher plant. The most common fungal partners of mycorrhiza are *Glomus species*. Mycorrhizal roots show a sparse or dense wooly growth of fungal hyphae on their surface. Root cap and root hairs are absent. The shape is irregular, tuberous, nodulated or coralloid. The fungus remains restricted to the cortex of the root. The vascular strand and growing point are not affected. Mycorrhiza often remains in the upper layers of the soil where organic matter is abundant. Depending upon the residence of the fungus, mycorrhizae are of two types—ectomycorrhiza and endomycorrhiza.

(a) **Ectomycorrhiza** (= Ectotrophic Mycorrhiza). The fungus forms a mantle on the surface of the root. Internally, it lies in the intercellular spaces of the cortex. The root cells secrete sugars and other food ingredients into the intercellular spaces for feeding the fungal hyphae. The exposed fungal hyphae increase the surface of the root to several times. They perform several functions for the plant— (i) Absorption of water. (ii) Solubilisation of

organic matter of the soil humus, release of inorganic nutrients, absorption and their transfer to root. (iii) Direct absorption of minerals from the soil over a large area and handing over the same to the root. Plants with ectomycorrhiza are known to absorb 2–3 times more of nitrogen, phosphorus, potassium and calcium. (iv) The fungus secretes antimicrobial substances which protect the young roots from attack of pathogens. Ectomycorrhiza occurs in the trees like *Eucalyptus*, Oak (*Quercus*), Peach, Pine, etc. The fungus partner is generally specific. It belongs to basidiomycetes.

(b) **Endomycorrhiza** (= Endotrophic Mycorrhiza). Fewer fungal hyphae lie on the surface. The remaining live in the cortex of the root, mostly in the intercellular spaces with some hyphal tips passing inside the cortical cells, e.g., grasses, crop plants, orchids and some woody plants. In seedling stage of orchids, the fungal hyphae also provide nourishment by forming nutrients rich cells called **pelotons**. Intracellular growth occurs in order to obtain nourishment because unlike ectomycorrhiza, the cortical cells do not secrete sugars in the intercellular spaces. The hyphal tips passing into cortical cells either produce swollen vesicles or finely branched masses called **arbuscules**. Therefore, endomycorrhiza is also called **VAM** or **vesicular-arbuscular mycorrhiza**. The major benefits of VAM to the plant is the supply of inorganic nutrients as well as enhanced water absorption. Phosphate which is mostly present in the unavailable form in the soil, becomes abundantly available to the plant. A single fungus may form mycorrhizal association with a number of plants, e.g., *Glomus*.

Importance of Biofertilizers

(i) They increase the yield of plants by 15–35%. (ii) Biofertilizers are effective even under semi-arid conditions. (iii) Farmers can prepare the inoculum themselves. (iv) They improve soil texture. (v) Biofertilizers do not allow pathogens to flourish. (vi) They produce vitamins and growth promoting biochemicals. (vii) They are nonpolluting.

ADDITIONAL INFORMATION

- **Bioprospecting.** Scanning of microbes, plants and animals for useful biochemicals and genetic resources.
- **Pasteurisation.** Preservation of milk, alcoholic beverages and other liquids by heating in thin layers briefly below their boiling point followed by sudden cooling, e.g., 70°C for 15 seconds or 63°C for 30 min in case of milk. Pasteurised milk can be kept for 2–5 days.
- Tissue culture technique is also being applied in the production of specific chemical substances synthesized naturally by plant cells. These substances include— hormones, enzymes, vitamins, steroids, gums, resins, latex, etc.
- **IPM.** Integrated Pest Management.
- To minimise the hazardous effects of chemical pesticides, attempts are being made these days to develop plant-based pesticides. An insecticide from Neem (*Azadirachta indica*) has been developed in the USA as a dust and spray.
- A safe herbal pesticide from garlic and chilies has been developed in Pune (Maharashtra).
- Scientists at CDRI in Lucknow developed **Biocide** from the microorganism *Bacillus sphaericus* which is highly effective formulation to control the mosquito menace.
- **Alexander Fleming** (1881–1955) discovered lysozyme (1922) and penicillin (1928).
- **Antibiosis.** It was first demonstrated by Babes (1855). The term was coined by Vuillemin (1899). Tyrothricin from *Bacillus brevis* was obtained by Rene Dubois prior to discovery of penicillin by Fleming.
- **Prebiotics.** They are nondigestible food ingredients that stimulate the growth of bacteria in the digestive tract.

NCERT TEXT BOOK QUESTIONS WITH ANSWERS

1. Bacteria cannot be seen with the naked eyes, but these can be seen with the help of a microscope. If you have to carry a sample from your home to your biology laboratory to demonstrate the presence of microbes under a microscope, which sample would you carry and why ?
✓ Sample of curd can be taken. It contains Lactic Acid Bacteria (LAB).
2. Give examples to prove that microbes release gases during metabolism.
✓ Dough for bread, dosa and idli swells up within a few hours of being inoculated with fermenting microbes. Heat expels the gases and makes the product spongy.
3. In which food would you find lactic acid bacteria ? Mention some of their useful applications.
✓ Lactic acid bacteria occur in curd. These bacteria convert lactose sugar into lactic acid. Lactic acid causes curdling of milk by coagulation and partial digestion of milk protein casein. Lactic acid bacteria improve the nutritional quality of curd by increasing vitamin B₁₂. They also check growth of disease-causing microbes in stomach and other parts.
4. Name some traditional Indian foods made of wheat, rice and Bengal gram (or their products) which involve use of microbes.

✓ Traditional Indian Foods (i) Dosa, Idli (Rice) (ii) Gutta (Black Gram) (iii) Bread (wheat)	Microbes used Fermented by bacteria Bacteria Baker's yeast
--------------------------------------------------------------------------------------------------------------	----------------------------------------------------------------------------
5. In which way have microbes played a major role in controlling diseases caused by harmful bacteria?
✓ Microbes have yielded a number of **antibiotics** that have been successfully used against pathogenic and other harmful bacteria.
6. Name any two species of fungus, which are used in the production of the antibiotics.
✓ (i) *Penicillium chrysogenum* gives penicillin. (ii) *Streptomyces griseus* gives streptomycin.
7. What is sewage ? In which way can sewage be harmful to us ?
✓ Sewage is municipal waste water that carries human excreta and other organic wastes.
Harmful effects. (i) It carries a number of pathogens. About 21% of all human diseases are caused by water borne pathogens. (ii) Sewage contains toxic chemicals extremely harmful to humans and animals. (iii) It causes eutrophication of water bodies.
8. What is the key difference between primary and secondary sewage treatment ?

✓ Primary Sewage Treatment (i) It is physical process of removal of floating, suspended and settleable solids from the sewage through filtration and sedimentation.	Secondary Sewage Treatment (i) It is biological process of digestion of organic matter by microbes.
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	---------------------------------------------------------------------------------------------------------------
9. Do you think microbes can also be used as source of energy ? If yes, how ?
✓ Microbes are not a direct source of energy but help produce efficient biofuels from organic matter under anaerobic conditions, e.g., biogas, alcohol.
10. Three water samples namely river water, untreated sewage water and secondary effluent discharged from a sewage treatment plant were subjected to BOD test. The samples were labelled A, B and C; but the laboratory attendant did not note which was which. The BOD values of the three samples A, B and C were recorded as 20 mg/L, 8mg/L and 400 mg/L, respectively. Which sample of the water is most polluted ? Can you assign the correct label to each assuming the river water is relatively clean ?
 ✓ Sample A, having BOD 20 mg/L, is secondary effluent discharged from a sewage treatment plant.
 Sample B, having least BOD 8 mg/L, is river water.
 Sample C, having highest BOD 400 mg/L, is untreated sewage water.
11. Find out the name of the microbes from which cyclosporin A (an immunosuppressive drug) and statins (blood cholesterol lowering agents) are obtained.
✓ (i) Cyclosporin A is obtained from the fungus *Trichoderma polysporum*. (ii) Statins are produced by yeast *Monascus purpureus*.
12. Find out the role of microbes in the following and discuss it with your teacher.
 (i) Single cell protein (SCP), (ii) Soil

- ✓ (i) **Single Cell Protein (SCP)** is protein rich microbial biomass which can be used as food and feed. SCP has all the essential amino acids. Fat content is low. Both autotrophs and heterotrophs are used as SCP. Amongst autotrophs, *Spirulina* has become an important food supplement which is used in various forms including tablets. It has 60% protein, all minerals, vitamins and unsaturated fats. Amongst heterotrophs, yeast and mushrooms are being raised as SCP. There is an increasing use of low cost organic matter (saw dust, paddy husk and other organic wastes) for raising SCP like *Fusarium graminearum* and common mushrooms. (ii) **Soil.** Microbes take part in formation and maintenance of soil. (a) They add organic matter to freshly formed soil. The process is called **humification**. (b) They act as scavengers and remove organic remains. (c) Microbes take part in biogeochemical circulation. (d) Some microbes act as biofertilizers and biopesticides.
13. Arrange the following in the decreasing order (most important first their importance, for the welfare or human society. Give reason for your answer). Biogas, Citric acid, Penicillin and Curd.
- ✓ (i) **Penicillin** — It is used to obtain antibiotic which is used to cure many bacterial diseases.
(ii) **Biogas** — It is an ecofriendly source of energy particularly in rural areas.
(iii) **Curd** — It is easily digestible vitamin rich food.
(iv) **Citric acid** — It is used mainly as preservative of many food items.
14. How do biofertilizers enrich the fertility of the soil ?
- ✓ Biofertilizers are micro-organisms which bring about nutrient enrichment of soil by enhancing their availability (i) **Manures**. They are semidecayed organic remains of various types — farmyard manure, green manure, compost and vermicompost. As the manure decay further takes place they release minerals locked in them. (ii) **Nitrogen Fixing Organisms**. They are certain bacteria and cyanobacteria which are capable of converting gaseous nitrogen into salts of nitrogen (e.g., ammonium → amino acids). (iii) **Mycorrhiza**. It is an association between a fungus and roots of plants. Mycorrhiza is able to pick up inorganic nutrients from organic matter.
15. Microbes can be used to decrease the use of chemical fertilizers and pesticides. Explain how this can be accomplished ?
- ✓ Chemical fertilizers and pesticides are costly as well as highly pollutant. They can be replaced by low cost non polluting biofertilizers and biopesticides. Biofertilizers not only provide the required nutrients to the crop plants but also improve soil texture. Biopesticides are target specific. They do not disturb the ecosystem but reduce the number of pests and pathogens.

TEXT QUESTIONS

One Mark Questions (With Answers)

1. Name one leguminous plant which has symbiotic relationship with two organisms in roots and stem?
✓ *Sesbania rostrata*.
2. Name any two free-living nitrogen fixing bacteria.
✓ *Azotobacter*, *Beijerinckia*.
3. What is Integrated Pest Management ?
✓ Integrated Pest Management is an important step taken by Government of India which involves the harmonious application of various 'Cultural controls' to insure minimum environmental pollution and proper maintenance of ecological balance.
4. Name the sources of biofertilizers.
✓ The main sources of biofertilizers are bacteria, cyanobacteria and fungi.
5. Name a biopesticide obtained from Neem.
✓ Azadirachtin.
6. Name the blue-green algae used as human food.
✓ *Spirulina*
7. Name the bacterium, that is first used as biopesticide.
✓ *Bacillus thuringiensis*
8. Name the fungus (apart from yeast) used for the production of SCP.
✓ *Fusarium graminearum*

9. What are Bioreactors ?
✓ In pilot plant, the glass vessels are replaced by stainless steel vessels. They are called **bioreactors**.
10. Name the enzymes which cause leavening.
✓ Amylase, Maltase, Zymase
11. In which respect immobilised yeast cells are more efficient than soluble ones ?
✓ Immobilised yeast cells bring about twenty times more rapid fermentation than the traditional batch process.
12. Name the first organic acid produced by microbial fermentation.
✓ Lactic acid.
13. Expand TPA. Give its importance.
✓ Tissue Plasminogen Activator. It is an enzyme obtained from the cultures of some haemolytic streptococci. It has fibrinolytic effect. Therefore, it helps in clearing blood clots inside the blood vessels through dissolution of intravascular fibrin.
14. Name the world's most problematic aquatic weed. What is the nature of water body in which the weed grows abundantly.
✓ *Eichhornia crassipes*. It grows in polluted eutrophic water body. (CBSE 2008)
15. What is economic value of Spirulina ?
✓ *Spirulina* (a blue green alga) is an SCP which is rich in proteins, vitamins, minerals, small quantity of fats and carbohydrates. It is used as supplementary food for humans and animals. (CBSE 2008)
16. Name the group of organisms and the substrates they act on to produce biogas.
✓ **Group.** Methanogens, **Substrates.** Dung and other organic remains. (CBSE 2009)
17. Which of the following is free living bacterium that can fix nitrogen in the soil ?
Spirulina, *Azospirillum*, Sonalika.
✓ *Azospirillum* (CBSE 2009)
18. Which one is Baker's Yeast : *Saccharomyces cerevisiae*, *Saccharomyces cerevisiae*, Sonalika. (CBSE 2009)
✓ *Saccharomyces cerevisiae*
19. Write the scientific name of microbe used for fermenting malted cereals and fruit juices. (CBSE 2011)
20. Mention the role of cyanobacteria as a biofertilizer. (CBSE 2012)
21. Name the type of association that genus *Glomus* exhibits with higher plants. (CBSE 2014)
22. Write an alternate source of protein for animal and human nutrition. (CBSE 2014)
23. What are *Cry* genes ? In which organism are they present ? (CBSE 2017)

Two Mark Questions (With Answers)

1. "Legumes fertilise the soils but cereals do not." Discuss.
✓ Leguminous plants are characterized by possessing root nodules where nitrogen is fixed by symbiotic bacteria *Rhizobium*. The fixed nitrogen fertilises the soil. The cereals, on the other hand, do not possess nitrogen fixing ability and, therefore, do not fertilise the soil.
2. A farmer adds *Azotobacter* culture to the soil before sowing maize. How does it increase the yield of maize ?
✓ *Azotobacter* is a free-living nitrogen-fixing bacteria. It fixes atmospheric nitrogen in the soil and increases the fertility of soil. Maize plants cultivated in fertile soil result in the increase in yield.
3. Name a green manure crop. How does it help in increasing the fertility of soil ?
✓ A green manure crop is *Crotolaria juncea*. The plants are leguminous which possess root nodules where N_2 is fixed by *Rhizobium* bacteria. Therefore, these plants enrich the soil by supplying fixed nitrogen, organic matter and other nutrients.
4. What is the biological significance of *Azolla pinnata* in agriculture ?
✓ The aquatic fern-*Azolla pinnata* has an important symbiotic association with nitrogen fixing cyanobacteria-*Anabaena azollae*. It grows in the rice fields and brings about soil enrichment in order to increase crop production.
5. Why are leguminous plants cultivated as green manure crop ?
✓ Leguminous plants possess root nodules where atmospheric nitrogen is fixed by symbiotic bacteria—*Rhizobium*. The fixed nitrogen fertilizes the soil. Moreover, the green plants provide manure by their death and decay.
6. What is mycorrhiza ? How does it help as biofertilizer ?
✓ Mycorrhiza is an association between the roots of a higher plant with a fungus. These fungi

solubilize phosphorus and produce growth promoting substance. They also protect the plant from soil pathogens.

7. During secondary treatment of primary effluent, how does significant decrease in BOD occur ?
(CBSE 2009)
8. How does addition of a small amount of curd to fresh milk help in formation of curd ? Mention a nutritional quality that gets added to the curd.
(CBSE 2010)
9. Name the enzyme produced by *Streptococcus* bacterium. Explain its importance in medical science.
10. Why are some molecules called bioactive molecules ? Give two examples of such molecules.
(CBSE 2011)
11. Name the source of cyclosporin-A. How does this bioactive molecule function in our body ?
(CBSE 2012)
12. Name the bacterium responsible for the large holes seen in "Swiss Cheese". What are these holes due to.
(CBSE 2013)
13. Why does the Bt toxin not kill the bacterium that produces it but kills the insect that ingests it?
(CBSE 2014)
14. Explain the significant role of genus *Nucleopolyhedrovirus* in an ecological sensitive area.
(CBSE 2014)
15. Explain the different steps involved during primary treatment of sewage.
(CBSE 2015)
16. Explain the process of secondary treatment given to the primary effluent upto the point it shows significant change in the level of biological oxygen demand (BOD) in it.
(CBSE 2015)
17. Mention a product of human welfare obtained with the help of each one of the following microbes.
(a) LAB (b) *Saccharomyces cerevisiae* (c) *Propionibacterium sharmanii* (d) *Aspergillus niger*.
(CBSE 2015)
18. Bottled fruit juices are cleaner as compared to those made at home. Explain.
(CBSE 2015)
19. List the events that lead to biogas production from waste water whose BOD has been reduced significantly.
(CBSE 2016)
20. Distinguish between roles of flocs and anaerobic sludge digesters in sewage treatments.
(CBSE 2016)
21. Name a genus of baculovirus. Why are they considered good biocontrol agents?
(CBSE 2016)
22. "Large scale cultivation of *Spirulina* is highly advantageous for human population". Explain giving two reasons.
(CBSE 2016)
23. Name the microbes that help in production of the following products commercially.
(a) Statin (b) Citric acid (c) Penicillin (d) Butyric acid.
(CBSE 2017)
24. Write the binomials of two yeasts/fungi and mention the products/bioactive molecules they help to produce.
(CBSE 2017)
25. How does the application of the fungal genus, *Glomus* to the agricultural farm increase the farm output?
(CBSE 2017)
26. How does the application of cyanobacteria help improve agriculture output?
(CBSE 2017)
27. How do mycorrhizae help the plants to grow better ?
(CBSE 2017)
28. "Growing *Spirulina* on a large scale is beneficial both environmentally and nutritionally for humans". Justify.
(CBSE 2017)

Three Mark Questions (Short Answer type)

1. (a) Baculoviruses are excellent candidates for integrated pest management in an ecologically sensitive area.
2. Explain giving two reasons. (b) What is organic farming ? Why is it suggested to switch over to organic farming ?
(CBSE 2009)
3. Mention the product and its use produced by each of the microbes listed below : (i) *Streptococcus* (ii) *Lactobacillus* (iii) *Saccharomyces cerevisiae*.
(CBSE 2010)
4. Identify a, b, c, d, e and f in the table given below

Organism	Bioactive Molecule	Use
1. <i>Monascus purpureus</i>	a	b
2. c	d	Antibiotic
3. e	Cyclosporin A	f

✓ (a) Statin (b) Cholesterol lowering (c) *Penicillium notatum* (d) Penicillin (e) *Trichoderma polysporum* (f) Immunosuppressive.

5. Name the genus to which baculoviruses belong. Describe their role in integrated pest management programmes. (CBSE 2011)

6. The diagram is that of a typical biogas plant. Explain the sequence of events occurring in a biogas plant. Identify a, b, c. (CBSE 2011)

Hints. a — sludge, b — gas holder, c — dung + water

7. (a) Why do farmers prefer biofertilizers to chemical fertilizers these days? Explain.

(b) How do *Anabaena* and mycorrhiza act as biofertilizers. (CBSE 2011)

8. Describe how biogas is generated from activated sludge. List the components of biogas. (CBSE 2013)

9. What are methanogens? Name the animals they are present in and the role they play there. (CBSE 2014)

10. State the medicinal value and the bioactive molecules produced by *Streptococcus*, *Monascus* and *Trichoderma*. (CBSE 2015)

11. What are methanogens? How do they help to generate biogas? (CBSE 2015)

12. Choose any three microbes, from the following which are suited for organic farming which is in great demand these days for various reasons. Mention one application of each one chosen: *Mycorrhiza*, *Monascus*, *Anabaena*, *Rhizobium*, *Methanobacterium*, *Trichoderma*. (CBSE 2015)

13. How can sewage be used to generate biogas? Explain. (CBSE 2015)

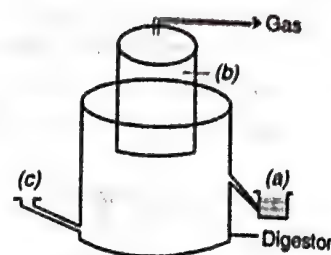
14. Given below is a list of six micro-organisms. State their usefulness to humans. (a) *Nucleopolyhedrovirus* (b) *Saccharomyces cerevisiae* (c) *Monascus purpureus* (d) *Trichoderma polysporum* (e) *Penicillium notatum* (f) *Propionibacterium sharmanii*. (CBSE 2016)

15. (a) How do organic farmers control pests? Give two examples.

(b) State the difference in their approach from that of conventional pest control methods. (CBSE 2016)

16. Secondary treatment of the sewage is also called biological treatment. Justify this statement and explain the process. (CBSE 2017)

17. Describe how do "flocs" and "activated sludge" help in sewage treatment. (CBSE 2017)



Five Mark Questions

- Name the major enzymes used in industry and explain their importance.
- Briefly describe the household products produced through the agency of microbes.
- Discuss the mechanism of alcoholic fermentation for producing beverages.
- What are antibiotics? Describe the production of methodology (manufacture) of antibiotics from microbes.
- Discuss the role of microbes as biofertilizers.
- Explain the process of sewage water treatment before it can be discharged into natural water bodies. Why is this treatment essential? (CBSE 2014)
- What are bio-fertilizers? Describe their role in agriculture. Why are they preferred to chemical fertilizers? (CBSE 2015)

Value Based Question

- Your mother adds less than a spoon of curd into a litre of warm milk and covers the same. Within 4-5 hours, the whole milk is converted into curd. How does it happen? What is the value of this practice?
✓ Your mother has inoculated the milk with small amount of curd that contains a number of lactic acid bacteria (LAB), *Lactobacillus acidophilus*. The bacteria multiply rapidly through binary fission. It secretes chemicals that convert lactose sugar into lactic acid. Lactic acid causes partial digestion of milk protein casein and its coagulation. This changes milk into curd.
Curd is more nutritious than milk. Besides having all the ingredients of milk it contains a number of organic acids and vitamins including B₁₂. LAB present in curd also checks the growth of disease causing microbes in the digestive tract.
- Despite using chemical fertilizer, a farmer was unable to get a good crop of paddy from his farm. He consulted an agriculture scientist who advised him to inoculate the fields with water fern *Azolla*. What is the rationale behind the advice? What value is provided by it?

✓ *Azolla* is a biofertilizer. It contains nitrogen fixing cyanobacterium *Anabaena* as symbiont. A part of the fixed nitrogen directly passes into paddy field while the rest is made available to the field after death of *Azolla*. *Azolla*, therefore, enriches the field with nitrogen as well as organic matter. On decomposition, organic matter releases minerals. It also maintains health of the soil. All these help improve the yield of crop. The quality of the product is also improved due to absence of chemical fertilizers.

Multiple Choice Questions

- (1) The product of which of the following organisms has been commercialised as blood cholesterol lowering agent (a) *Trichoderma polysporum* (b) *Monascus purpureus* (c) *Saccharomyces cerevisiae* (d) *Aspergillus niger*. (AMU 2010)
- (2) Example of endomycorrhiza is (a) *Glomus* (b) *Agaricus* (c) *Nostoc* (d) *Rhizobium*. (CBSE Mains 2010)
- (3) Which of the following is mainly produced by the activity of anaerobic bacteria on sewage (a) Mustard gas (b) Marsh gas (c) Laughing gas (d) Propane. (CBSE 2011)
- (4) Which is wrongly matched (a) *Clostridium butylicum* — Lactic acid (d) *Aspergillus niger* — Citric acid (c) Yeast — Statins (d) *Acetobacter aceti* — Acetic acid. (CBSE Mains 2011)
- (5) Nitrogen fixing microbe associated with *Azolla* in rice fields is (a) *Frankia* (b) *Tolypothrix* (c) *Spirulina* (d) *Anabaena*. (CBSE 2012)
- (6) In gobar gas the maximum amount is that of (a) Propane (b) Methane (c) Butane (d) Carbon dioxide. (CBSE Mains 2012)
- (7) A good producer of citric acid is (a) *Aspergillus* (b) *Pseudomonas* (c) *Saccharomyces* (d) *Clostridium*. (NEET 2013)
- (8) Biogases produced during sewage treatment are (a) H_2S , N_2 , CH_4 (b) CH_4 , H_2S , CO_2 (c) CH_4 , O_2 , H_2S (d) H_2S , CH_4 , SO_2 . (NEET 2013)
- (9) Microorganism used for commercial production of acetic acid is (a) *Aspergillus* (b) *Acetobacter* (c) *Clostridium* (d) *Saccharomyces*. (JK CET 2014)
- (10) Which is true (a) Antibiotics are of microbial origin but disinfectants are chemical compounds (b) Antibiotics can be injected into patients where as disinfectants are not (c) Antibiotic can kill bacteria but disinfectants do not (d) both (a) and (b). (WB 2014)
- (11) Which one of the following insecticides is of plant origin ? (a) Ecdysone (b) Rotenone (c) Parathion (d) Malathion. (W. B. 2015)
- (12) Yeast is used in the production of (a) cheese and butter (b) Citric acid and lactic acid (c) Bread and beer (d) Lipase and pectinase. (JKCET 2015)
- (13) Large holes in Swiss cheese are formed due to production of a large amount of CO_2 by (a) *Propionebacterium* (b) *Mycobacterium* (c) *Saccharomyces* (d) *Penicillium*. (AMU 2016)
- (14) Which of the following act as biofertilisers (a) Blue green algae (b) Green algae (c) Yellow algae (d) Red algae. (Pb PMT 2016)
- (15) Which of the following is correctly matched for the product produced by them ? (a) *Methanobacterium* : Lactic acid (b) *Penicillium notatum* : Acetic acid (c) *Saccharomyces cerevisiae* : Ethanol (d) *Acetobacter aceti* : Antibiotics. (NEET 2017)
- (16) Select the mismatch (a) *Frankia* — *Alnus* (b) *Rhodospirillum* — Mycorrhiza (c) *Anabaena* — Nitrogen fixer (d) *Rhizobium* — Alfalfa. (NEET 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—

- (a) If both A and R are true and R is the correct explanation of A
- (b) If both A and R are true and R is not the correct explanation of A
- (c) If A is true but R is false
- (d) If both A and R are false.

1. **Assertion:** Integrated pest management programme involves harmonious application of various 'culture controls' to insure minimum environmental pollution and proper maintenance of ecological balance.

Reason: Integrated pest management programme is an important step taken by the Government of India.

A B C D

2. **Assertion:** Sustainable agriculture aims to provide food and livelihood for present and future generations.

Reason: Different countries and societies are observing strict environmental standards in developing advance technologies in the field of agriculture.

A B C D

3. **Assertion:** Use of fertilizers greatly enhances crop productivity.

Reason: Irrigation is very important in increasing crop productivity.

(AIIMS 2003)

A B C D

4. **Assertion:** Nitrogen-fixing bacteria in legume root nodules survive in oxygen-depleted cells of nodules.

Reason: Leghaemoglobin completely removes oxygen from the nodule cells.

(AIIMS 2004)

A B C D

5. **Assertion:** While working on staphylococci, Alexander Fleming observed that *Penicillium notatum* inhibits the growth of bacteria.

Reason: The inhibiting chemical was commercially extracted and its full potential was established by Alexander Fleming.

(AIIMS 2013)

A B C D

6. **Assertion:** *Saccharomyces cerevisiae* produces acetic acid.

Reason: *Trichoderma polysporum* produces blood cholesterol lowering agent.

(AIIMS 2013)

A B C D

7. **Assertion:** Curdling is required in the manufacture of cheese.

Reason: Lactic acid bacteria are used for the purpose.

(AIIMS 2016)

A B C D

8. **Assertion:** Endomycorrhiza of forest trees contribute to the efficient nutrient cycling in tropical forest ecosystems.

Reason: The fungi that form mycorrhizal association with plants make nutrient ions available to them.

A B C D (AIIMS 2017)

ANSWERS

Multiple Choice Questions

(1) —b (2) —a (3) —b (4) —a (5) —d (6) —b (7) —a (8) —b (9) —b (10) —d
(11) —b (12) —c (13) —a (14) —a (15) —c (16) —b

Assertion Type Questions

1. —B 2. —A 3. —B 4. —D 5. —C 6. —D 7. —B 8. —A

BIOTECHNOLOGY: PRINCIPLES AND PROCESSES

Some Nick-Names In Biotechnology

1. Gene taxi — Plasmid
2. Workhouse for gene cloning — pBR322 (an artificial plasmid)
3. Molecular scissor — Restriction endonuclease
4. Chemical scalpel — Restriction endonuclease
5. Molecular glues — Ligases
6. Chemical knives — Restriction endonucleases
7. Natural genetic engineer — *Agrobacterium tumefaciens*
8. Mobile genetic element — Transposon
9. Passenger DNA — Foreign DNA

Biotechnology deals with techniques of using live micro-organisms, plant or animal cells or their components or enzymes from organisms to produce products and processes (services) useful to human beings.

The term biotechnology was coined in 1917 by a Hungarian Engineer, **Karl Ereky** to describe a process for large scale production of pigs.

Gene manipulation is a fast emerging science. It started with the development of recombinant DNA molecules. It is named variously as **DNA manipulation biotechnology**, **recombinant DNA technology** and **genetic engineering**. The technology mostly involves cutting and pasting of desired DNA fragments. It is based on two important discoveries in bacteria: (i) Presence of *plasmids in bacteria* which can undergo replication alongwith and independent of chromosomal DNA. (ii) *Restriction endonucleases* (Arber, Nathan and Smith 1970; Nobel Prize in 1978) which can break DNA at specific sites. They are appropriately called **molecular scissors**. Berg (1972) was able to introduce a gene of SV-40 into a bacterium with the help of lambda phage. Berg is often considered "**father of genetic engineering**". He was awarded Nobel Prize in Chemistry in 1980. The science of recombinant technology took birth when Cohen and Boyer (1973) were able to introduce a piece of gene containing foreign DNA into plasmid of *Escherichia coli*.

Old Biotechnology (Traditional Biotechnology)

Microorganisms were first used to produce some organic compounds like citric acid. They were also used to produce antibodies. The levels of production of penicillin yield has been improved. But the types of products have not changed. They remain the same as those obtained from the natural strains/cell lines. In all these processes, only the natural capabilities of the organisms and cells are exploited. These activities are called **old biotechnology**.

Modern Biotechnology

Human insulin is also produced from a transgenic *Escherichia coli* strain that contains and

expresses the insulin gene. Proteins produced by transgenes are called **recombinant proteins**. The production technologies based on genetic engineering are termed as **modern biotechnology**. It developed during 1970.

Definition of Biotechnology

A definition of biotechnology which covers both traditional views and modern molecular biotechnology has been given by European Federation of Biotechnology (EFB). According to EFB, "*Biotechnology is the integrated use of biochemistry, microbiology and engineering sciences in order to achieve technological (industrial) application of the capabilities of microorganisms, cultured tissues/cells and parts thereof*".

Thus definition of biotechnology involves two common factors. First the use of biological agents and second the product or service is generated for the well being of humans.

I. PRINCIPLES OF BIOTECHNOLOGY

Two Main Techniques of Modern Biotechnology. The two main techniques that gave birth to modern biotechnology are as follows :

(a) **Genetic Engineering.** It includes techniques to alter the nature of genetic material (DNA and RNA) to introduce these into host organisms and thus change the phenotype of the host organism.

(b) **Chemical Engineering.** It involves maintenance of sterile microbial contamination free condition in chemical engineering processes to have growth of only the desired micro-organism/eukaryotic cell in large quantities for the manufacture of biotechnological products such as antibiotics, vaccines, enzymes, medicines, hormones, etc.

1. Conceptual Development of the Principles of Genetic Engineering

Genetic engineering is a kind of biotechnology which deals with the manipulation of genetic material by man *in vitro*.

Two Main Discoveries. Genetic engineering is based on two important discoveries in bacteria.

(i) **Presence of plasmids in bacteria** which can undergo replication alongwith and independent of chromosomal DNA.

(ii) **Restriction endonucleases** (Arber, Nathan and Smith 1970; Nobel Prize in 1978) which can break DNA at specific sites. They are appropriately called **molecular scissors** or **biological scissors**.

Role of Paul Berg. In 1972 genetic engineering was started by **Paul Berg**. Berg (1972) was able to introduce a gene of SV-40 virus into a bacterium with the help of lambda phage. Berg is often considered "**father of genetic engineering**". He was awarded Nobel Prize in 1980.

The technique of genetic engineering includes :

(i) **Formation of 'recombinant DNA' (rDNA).**

(ii) **Use of gene cloning.**

(iii) **Gene transfer.** It permits to isolate and introduce only one or a set of desirable genes without introducing undesirable genes into the target organism.

A piece of DNA which is introduced into the alien (foreign) organism would not be able to multiply itself in the organism but when it gets incorporated into the genetic material of the recipient, it may multiply and be inherited alongwith the host DNA, because the alien piece

of DNA has become part of chromosome which possesses the ability to replicate. There is a specific DNA sequence called the **origin of replication** in a chromosome that is responsible for initiating replication. Thus, an alien DNA linked with the origin of replication, can replicate and multiply itself in the host organism. It is also called the **cloning**, i.e., forming multiple identical copies of any template DNA.

2. Construction of the First Artificial Recombinant DNA Molecule.

The first recombinant DNA was constructed by **Stanley Cohen and Herbert Boyer** in 1972. They cut the piece of DNA from a plasmid carrying antibiotic resistance gene in the bacterium *Salmonella typhimurium*. Cutting of a piece of DNA from a plasmid was with the help of **restriction enzymes** (also called **molecular scissors** or **chemical scalpels**). The piece of foreign DNA cut from the plasmid was linked with the plasmid DNA acting as **vector**. Linking of the piece of foreign DNA with vector was done with the help of the enzyme **DNA ligase** which acts on cut DNA molecules and join their ends. This newly formed DNA having integrated fragment of antibiotic resistant gene is called **recombinant DNA**. The vector is used to transfer, recombinant DNA to *E.coli*. This transfer of recombinant DNA is similar to the transfer of malarial parasite from diseased person into the healthy person through female Anopheles mosquito (acts as an insect vector). When this recombinant DNA is transferred into *Escherichia coli*, it could replicate in the new host cell in the presence of **DNA polymerase enzyme** and make multiple copies of recombinant DNA. The ability to multiply copies of antibiotic resistance gene in *E. coli* was termed as **cloning** of antibiotic resistance gene in *E. coli*.

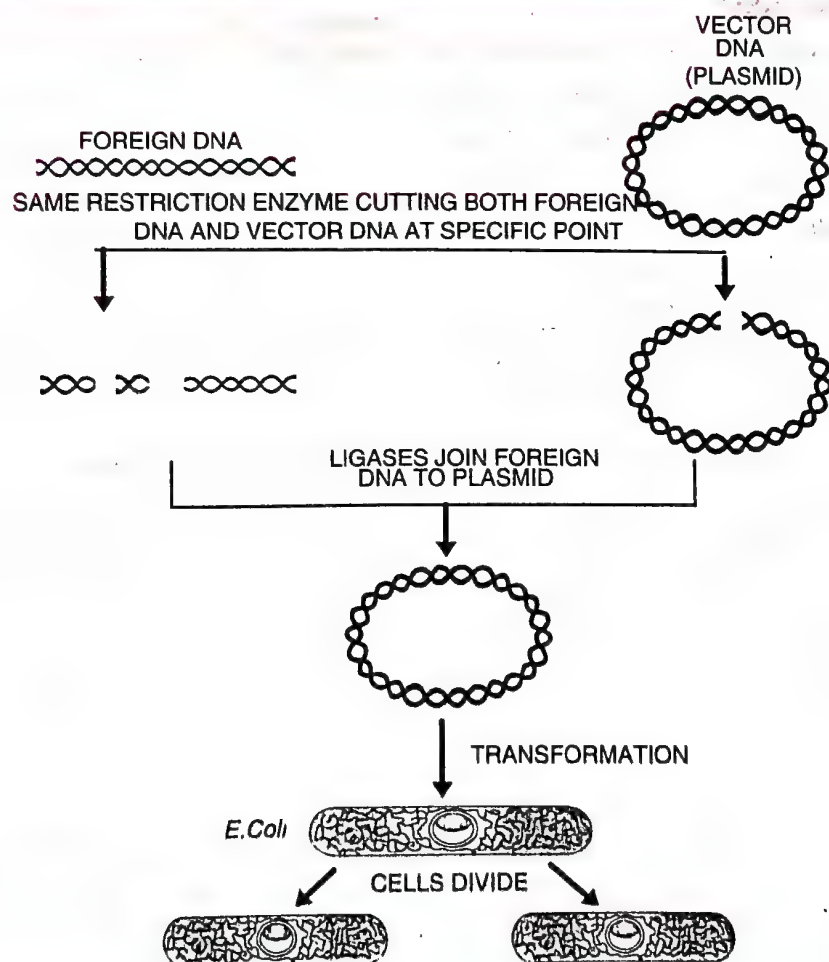


Fig. 11.1. Diagrammatic representation of recombinant DNA technology.

Three basic steps in creating genetically modified organism (GMO) or transgenic organism. GMO contains a foreign gene/segment of DNA. These three basic steps are as follows.

- (i) Identification of DNA with desirable genes.
- (ii) Introduction of the identified DNA into the host.
- (iii) Maintenance of introduced DNA in the host and transfer of the DNA to its progeny.

II. TOOLS OF RECOMBINANT DNA TECHNOLOGY

Three types of "biological tools" are used in the formation of recombinant DNA. These are as follows :

- (A) Enzymes
- (B) Cloning Vectors (Vehicle DNA)
- (C) Competent host (for transformation with recombinant DNA)

(A) Enzymes

(1) **Lysing Enzymes.** These enzymes are used to open up the cells to get DNA for genetic experiments. **Lysozyme** is usually used to dissolve the bacterial cell wall. In plant cell, cell wall is made up of **cellulose**, while in fungi, it is made up of **chitinase**.

(2) **Cleaving Enzymes.** These enzymes are used to break DNA molecules. They are of three types—exonucleases, endonucleases and restriction endonucleases.

(a) **Exonucleases.** They remove nucleotides from the terminal ends (either 5' or 3') of DNA in one strand of duplex.

(b) **Endonucleases.** They make cuts at specific position within the DNA. These enzymes do not cleave the ends and involve only one strand of the DNA duplex.

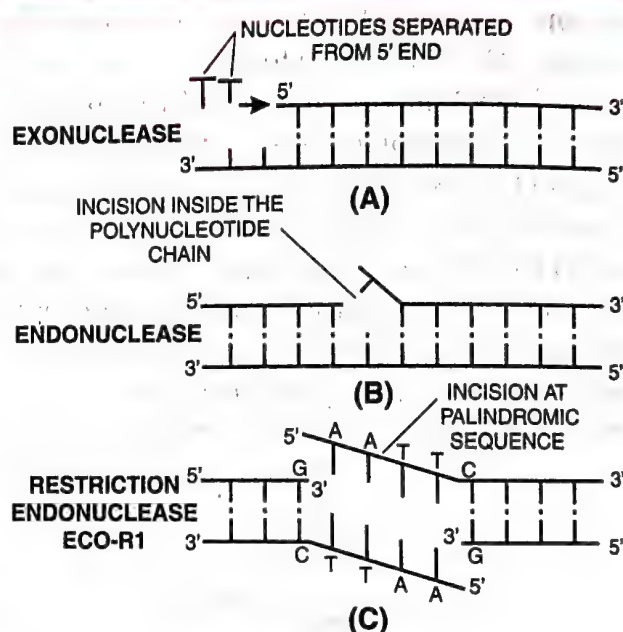


Fig.11.2. A, Action of exonuclease. B, Action of endonuclease. C, Action of restriction enzyme.

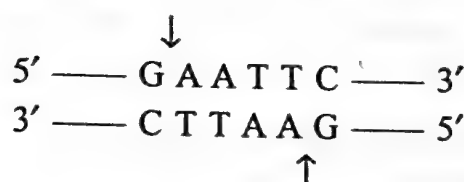
Differences Between Exonucleases and Endonucleases

Exonucleases	Endonucleases
<ol style="list-style-type: none"> 1. These nucleases cleave base pairs of DNA at their terminal ends. 2. They act on single strand of DNA or gaps in double stranded DNA. 3. They do not cut RNA. 	<ol style="list-style-type: none"> 1. They cleave DNA at any point except the terminal ends. 2. They cleave one strand Fig. (a) or both strands Fig. (b) of double stranded DNA. 3. They may cut RNA.

(c) **Restriction endonucleases.** They cut DNA duplex at specific points. Their single stranded free ends are called 'sticky ends' (Fig. 11.3) which can be joined end to end by DNA ligases.

Restriction Endonucleases — The Molecular Scissors

Restriction endonuclease was isolated for the first time by W. Arber in 1962 in bacteria. They are called "molecular scissors or biological scissors". In 1978 Arber, Smith and Nathan were awarded the Nobel Prize for the discovery of restriction endonuclease. They recognize the base sequence at palindrome sites in DNA duplex and cut its strands. For example, restriction endonuclease EcoR 1 found in the colon bacteria *E.coli*, recognizes the base sequence GAATTC in DNA duplex and cuts its strands between G and A as shown below :



Only restriction enzymes type II are used in gene manipulation for two reasons. (a) No ATP is needed for the cleaving action. (b) It makes cleavage or cut in both the strands of DNA molecule.

(1) **Types of Restriction Endonucleases.** Three main types of restriction endonucleases are type I, type II and type III.

Type I Restriction Endonucleases. These enzymes consist of 3 different subunits. They require ATP, Mg^{2+} and S-adenosyl methionine for restriction. Type I restriction endonucleases recognize specific sites within the DNA but do not cut these sites. Thus they are not used in recombinant DNA technology.

Type II Restriction Endonucleases. These enzymes are simple and require Mg^{2+} ions for restriction. *Out of the three types, only type II restriction enzymes are used in recombinant DNA technology.*

Type III Restriction Endonucleases. These enzymes consist of two different subunits. They require ATP, Mg^{2+} and S-adenosyl methionine for restriction. They recognize specific sites within DNA but do not cut these sites, therefore, these restriction endonucleases are not used in recombinant DNA technology. They have intermediate properties between type I and type II.

Differences Between Type I, Type II and Type III Restriction Endonucleases

Type I	Type II	Type III
1. Enzyme structure consists of 3 different subunits.	Enzyme structure is simple.	Enzyme structure consists of two different subunits.
2. They require ATP, Mg^{2+} and S-adenosyl-methionine for restriction.	They require Mg^{2+} ions for restriction.	They require ATP, Mg^{2+} and S-adenosyl-methionine for restriction.
3. They recognize specific sites within DNA but do not cut these sites.	They recognize specific sites within the DNA and cut these sites.	They recognize specific sites within the DNA but do not cut these sites.
4. They are not used in recombinant DNA technology.	They are used in recombinant DNA technology.	They are not used in recombinant DNA technology.

(2) **Nomenclature of Restriction Enzymes.** (i) Type II restriction enzymes are named for the bacterium from which they have been isolated. (ii) The first letter used for the enzyme is the first letter of the bacterium's **genus** name (in italics). (iii) Then comes the first two letters of its species (also in italics). (iv) The fourth letter of the name of enzyme is first letter of the **strain**. It is written in capital. (v) The end of the name indicates the order in which the enzyme was isolated. It is written in Roman number. For example, the enzyme Eco R1 was isolated from the bacterium *Escherichia coli* RY13. Enzyme Eco R1 is named as follows.

The capital letter E comes from the genus *Escherichia*. The letters *co* are from the species *coli*. The letter **R** is from RY13 (strain). The Roman number 1 indicates that it was the first enzyme isolated from the bacterium *E.coli* RY13. The discovery of restriction endonuclease enzymes led to Nobel Prize for **W. Arber, H. Smith** and **D. Nathan** in 1978.

Some examples of type II enzymes are given in the table 11.1 showing names of restriction enzymes (endonucleases), source (organism from where they have been isolated), their recognition sequence and site of cleavage.

Table 11.1. Some common examples of restriction enzymes type II, their source, recognition sequence and site of cleavage.

Restriction Enzyme	Source	Recognition Sequence and Site of Cleavage	Product
1. <i>Alu</i> I	<i>Arthrobacter luteus</i>	$\begin{array}{c} 5'-A-G-C-T-3' \\ 3'-T-C-G-A-5' \\ \uparrow \end{array}$	<div style="display: inline-block; border: 1px solid black; padding: 2px;">A-G</div> <div style="display: inline-block; border: 1px solid black; padding: 2px;">C-T</div> <div style="display: inline-block; padding: 0 5px;">blunt ends</div>
2. <i>Bam</i> H I	<i>Bacillus amyloliquefaciens</i> H	$\begin{array}{c} 5'-G-G-A-T-C-C-3' \\ 3'-C-C-T-A-G-G-5' \\ \uparrow \end{array}$	<div style="display: inline-block; border: 1px solid black; padding: 2px;">G</div> <div style="display: inline-block; border: 1px solid black; padding: 2px;">G-A-T-C-C</div> <div style="display: inline-block; padding: 0 5px;">Sticky ends</div>
3. <i>Eco</i> R I	<i>Escherichia coli</i> RY13	$\begin{array}{c} 5'-G-A-A-T-T-C-3' \\ 3'-C-T-T-A-A-G-5' \\ \uparrow \end{array}$	<div style="display: inline-block; border: 1px solid black; padding: 2px;">G</div> <div style="display: inline-block; border: 1px solid black; padding: 2px;">A-A-T-T-C</div> <div style="display: inline-block; padding: 0 5px;">sticky ends</div>
4. <i>Eco</i> R II	<i>Escherichia coli</i> R245	$\begin{array}{c} 5'-C-C-T-G-G-3' \\ 3'-G-G-A-C-C-5' \\ \uparrow \end{array}$	<div style="display: inline-block; padding: 0 5px;">5' C-C-T-G-G-3'</div> <div style="display: inline-block; padding: 0 5px;">blunt ends</div>
5. <i>Hae</i> III	<i>Haemophilus aegyptius</i>	$\begin{array}{c} 5'-G-G-C-C-3' \\ 3'-C-C-G-G-5' \\ \uparrow \end{array}$	<div style="display: inline-block; border: 1px solid black; padding: 2px;">G-G</div> <div style="display: inline-block; border: 1px solid black; padding: 2px;">C-C</div> <div style="display: inline-block; padding: 0 5px;">blunt ends</div>
6. <i>Hin</i> d III	<i>Haemophilus influenzae</i> Rd	$\begin{array}{c} 5'-A-A-G-C-T-T-3' \\ 3'-T-T-C-G-A-A-5' \\ \uparrow \end{array}$	<div style="display: inline-block; border: 1px solid black; padding: 2px;">A</div> <div style="display: inline-block; border: 1px solid black; padding: 2px;">A-G-C-T-T</div> <div style="display: inline-block; padding: 0 5px;">sticky ends</div>
7. <i>Hin</i> d II (first discovered Restriction endonuclease)	<i>Haemophilus influenzae</i> Rd	$\begin{array}{c} 5'-G-T-C-G-A-C-3' \\ 3'-C-A-G-C-T-G-5' \\ \uparrow \end{array}$	<div style="display: inline-block; border: 1px solid black; padding: 2px;">G-T-C</div> <div style="display: inline-block; border: 1px solid black; padding: 2px;">G-A-C</div> <div style="display: inline-block; padding: 0 5px;">blunt ends</div>

8. <i>Sal</i> I	<i>Streptomyces albus</i>	$ \begin{array}{c} 5'-\text{G}-\text{T}-\text{C}-\text{G}-\text{A}-\text{C}-3' \\ 3'-\text{C}-\text{A}-\text{G}-\text{C}-\text{T}-\text{G}-5' \end{array} $	<p>Diagram showing the recognition sequence 5'-GTCGAC-3' and 3'-CAGCTG-5'. Cleavage occurs between G and A on both strands, resulting in 5' overhangs (sticky ends) of GTCGAC.</p>	sticky ends
9. <i>Sca</i> I	<i>Streptomyces caespitosus</i>	$ \begin{array}{c} 5'-\text{A}-\text{G}-\text{T}-\text{A}-\text{C}-\text{T}-3' \\ 3'-\text{T}-\text{C}-\text{A}-\text{T}-\text{G}-\text{A}-5' \end{array} $	<p>Diagram showing the recognition sequence 5'-AGTAC-3' and 3'-TCA-TGA-5'. Cleavage occurs between T and A on both strands, resulting in blunt ends.</p>	blunt ends
10. <i>Sma</i> I	<i>Serratia marcescens</i>	$ \begin{array}{c} 5'-\text{C}-\text{C}-\text{C}-\text{G}-\text{G}-\text{G}-3' \\ 3'-\text{G}-\text{G}-\text{G}-\text{C}-\text{C}-\text{C}-5' \end{array} $	<p>Diagram showing the recognition sequence 5'-CCCGGG-3' and 3'-GGGCC-5'. Cleavage occurs between C and G on both strands, resulting in blunt ends.</p>	blunt ends

(3) **Functioning of Restriction Endonuclease.** The foundations of recombinant DNA (rDNA) were laid by the discovery of **restriction enzymes**. These enzymes are present in many bacteria where they function as a part of their defence mechanism called the **Restriction Modification System**. Molecular basis of this system was explained first by **Wemer Arber** in 1965.

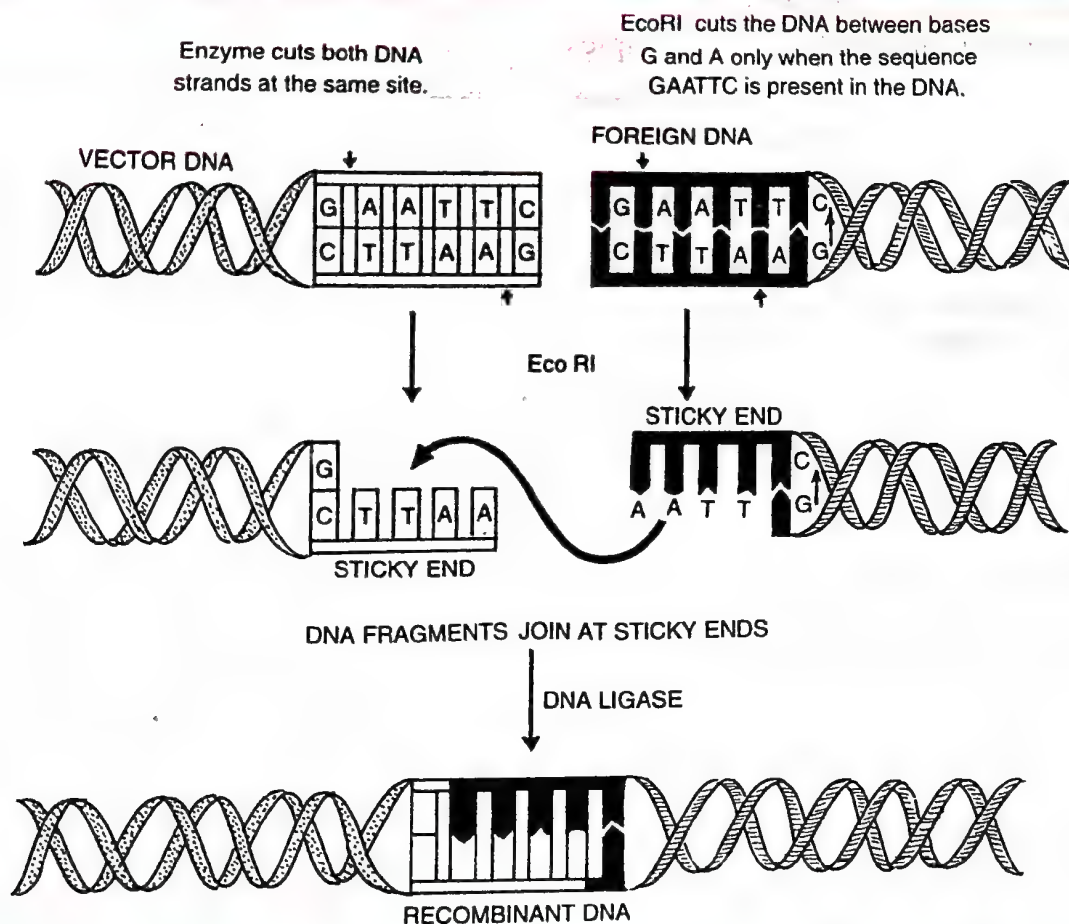


Fig.11.3. Steps in the formation of recombinant DNA by action of restriction enzyme Eco R1.

The Restriction-Modification system consists of two components ; (i) A **restriction enzyme** which identifies the introduced foreign DNA and cuts into pieces called **restriction endonucleases**. The term 'restriction' refers to the function of these enzymes in restricting the propagation of foreign DNA of bacteriophages (viruses that attack bacteria) in the host bacterium. (ii) The second component is a **modification enzyme** that adds a methyl group to one or two bases usually 'within' the sequence reorganized by the restriction enzyme.

Once a base in a DNA sequence is modified by addition of a methyl group, the restriction enzymes fail to recognize and could not cut that DNA. This is how a bacterium modifies and therefore, protects its own chromosomal DNA from cleavage by these restriction enzymes.

The first restriction endonuclease was **Hin d II** (hin-dee-two). Its functioning depended on a specific DNA nucleotide sequence. It was isolated from *Haemophilus influenzae* Rd. It was found that **Hin d II** always cut DNA molecules at a particular point by recognising a specific sequence of six base pairs. This specific base sequence is known as the **recognition sequence** for **Hin d II**. It produces blunt ends. Besides **Hin d II**, today we know more than 900 restriction enzymes that have been isolated from over 230 strains of bacteria each of which recognises different recognition sequences.

(4) **Palindromic Nucleotide Sequence.** The restriction endonuclease **inspects** the length of a DNA sequence. Once it recognises specific sequence, it binds to the DNA and cuts each of the two strands of the double helix at specific points in their sugar phosphate back bones. Special sequence in the DNA recognised by restriction endonuclease is called **palindromic nucleotide sequence**.

Restriction endonuclease recognizes palindromic sequences in DNA and cuts them.

The palindromes are groups of letters that form the same words when read in both directions forward and backward. Examples :

→	→
MALAYALAM	MADAM
←	←

The palindromes in DNA are base pair sequences that are the same when read forward (left to right) or backward (right to left) from a central axis of symmetry. For example, the following sequences read the same on the two strands in 5' → 3' direction. This is also true when we read in the 3' → 5' direction.

←	5' — G A A T T C — 3'	→
→	3' — C T T A A G — 5'	←

Palindromic sequence

Restriction enzymes cut the strand of DNA a little away from the centre of the palindromic sites but between the same two bases of the opposite strands. This leaves single stranded unpaired bases at cut ends. These ends with unpaired bases are called **sticky ends** or **cohesive ends** (Fig 11.3). The latter are named so because they form hydrogen bonds with their complementary cut counter parts. The sticky ends facilitate the action of the enzyme DNA ligase.

Gel Electrophoresis (Separation and Isolation of DNA Fragments). After the cutting of DNA by restriction enzymes, fragments of DNA are formed. Separation of DNA fragments according to their size or length is done by a technique called gel electrophoresis developed by A. Tiselius in 1937. **Electrophoresis** is a technique of separation of molecules such as DNA, RNA or protein on the basis of their size, under the influence of an electrical field, so that they migrate in the direction of electrode bearing the

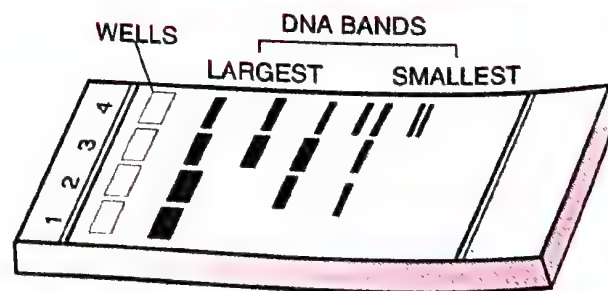


Fig. 11.4. A typical agarose gel electrophoresis showing migration of undigested (lane 1) and digested lanes of DNA fragments (lanes 2 to 4)

opposite charge, viz., positively charged molecules move towards cathode (-ve electrode) and negatively charged molecules travel towards anode (+ve electrode) through a **medium/matrix**. Electrophoresis performed in a gel matrix, so that molecules of similar electric charge can be separated on the basis of size, is called **gel electrophoresis**. Now a days the most commonly used matrix is **agarose** which is a polysaccharide extracted from sea weeds. DNA fragments separate according to size through the pores of agarose gel. Hence the smaller the fragment size the farther it moves.

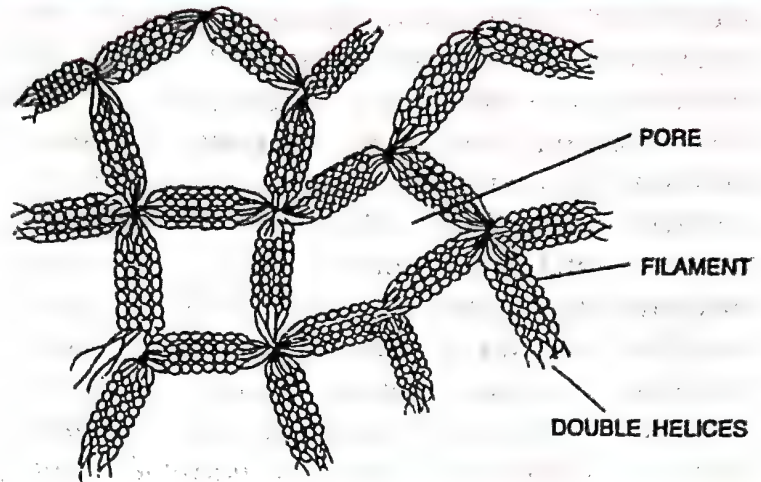


Fig. 11.5. Formation of pores in the agarose gel.

Agarose dissolves in hot water when this solution is cooled, double helices form and become arranged laterally and produce thick filaments. These filaments become cross-linked to form the gel (Fig. 11.5). Pore size depends on agarose concentration.

The separated DNA fragments can be seen only after staining the DNA with a compound known as **ethidium bromide** (EtBr) followed by exposure to UV radiation as bright orange coloured bands. The separated bands of DNA are cut out from the agarose gel and extracted from the gel piece. This process is called **elution** (removal of adsorbent). These purified DNA fragments are used in constructing recombinant DNA by linking them with cloning vectors.

Other Enzymes used in Cloning

(1) **DNA Ligases (Joining or Sealing Enzymes)**. They help in sealing gaps in DNA fragments. Therefore, they act as a **molecular glues**. The enzyme used most often in the rDNA technology is **T4 DNA ligase**. In 1969 **Har Govind Khorana** discovered DNA ligase in T_4 -bacteriophage.

(2) **Alkaline Phosphatase (AP)**. Alkaline phosphatase is an enzyme that removes a phosphate group from the 5' end of double stranded or single stranded DNA or RNA. If this phosphate group is removed, this DNA cannot be ligated.

(3) **Synthesizing Enzymes**. These enzymes are for the synthesis of DNA strands on suitable templates. These are of two types : Reverse transcriptase and DNA polymerase.

(a) **Reverse Transcriptase**. This enzyme is used to synthesize the DNA or complementary DNA (cDNA) by using mRNA as a template. It is very useful in the synthesis of cDNA. It was discovered by **Temin and Baltimore** in 1970.

(b) **DNA Polymerase**. This enzyme helps in the DNA synthesis on DNA template or complementary DNA (cDNA). The DNA polymerase was discovered by **A. Kornberg** and co-workers in *E. coli* in 1956.

(B) Cloning Vectors (Vehicle DNA or carrier of DNA)

The **vectors** are DNA molecules that can carry a foreign DNA segment and replicate inside the host cell. Vectors may be plasmids, bacteriophages (viruses that attack bacteria), cosmids, Yeast artificial chromosomes (YACs), Bacterial artificial chromosomes (BACs) and viruses. There are also some shuttle vectors. Out of these vectors, the most commonly used cloning vectors are plasmids and viruses.

(1) **Plasmid Vectors**. Plasmids were discovered by **William Hays and Joshua Lederberg** (1952). These are extra-chromosomal, self-replicating, usually circular, double-stranded

DNA molecules, found naturally in many bacteria and also in some yeast. Although plasmids are usually not essential for normal cell growth and division, they often confer some traits on the host organism, for example, resistance to certain antibiotics or toxins that can be a selective advantage under certain conditions. The plasmid molecules may be present as 1 or 2 copies or in multiple copies (500–700) inside the host organism. These naturally occurring plasmids have been modified to serve as vectors in the laboratory. *The most widely used, versatile, easily manipulated vector pBR 322 is an ideal plasmid vector.*

pBR322 Vector (Fig. 11.7)

This was the first artificial cloning vector constructed in 1977 by Boliver and Rodriguez. It is widely used in gene cloning experiments.

Nomenclature : In pBR 322 plasmid

p — denotes that it is a plasmid;

BR — stands for Boliver and Rodriguez who constructed this plasmid;

322 — is a number given to distinguish this plasmid from others developed in the same laboratory. For example, there are plasmids pBR 325, pBR 327, pBR 328, pBR 345 etc.

Features That are Required to Facilitate Cloning into a Vector

- (i) **Origin of Replication (*Ori*).** Origin of replication (*Ori*) is a specific sequence of DNA bases which is responsible for initiating replication. A prokaryotic DNA has a single origin of replication while eukaryotic DNA may have more than one origin of replication.
- (ii) **Selectable Markers.** Some genes called “**selectable markers**” help in selecting those host cells which contain the vectors (transformants) and eliminating the non-transformants. **Transformation** is a process through which a piece of DNA is introduced in a host bacterium. Generally, the genes encoding resistance to antibiotics such as tetracycline, ampicillin, kanamycin or chloramphenicol etc. are useful selectable markers for *E. coli*. The common *E. coli* cells are not resistant against any of these antibiotics. Plasmid pBR 322 has two resistance genes — **ampicillin resistance (amp^R)** and **tetracycline resistance (tet^R)** which are considered useful for selectable markers.
- (iii) **Cloning Sites (Recognition Sites).** Plasmid pBR 322 has a variety of unique recognition sites for restriction endonucleases. Two unique sites, *Pst* I and *Pvu* I are located within the amp^R gene and *Bam* HI, *Sal* I, etc. are within tet^R gene (Fig 11.7). Some other unique restriction sites are *Eco* RI, *Cla* I, *Hind* III, *Pvu* II, *rop* codes for the proteins involved in the replication of the plasmid.

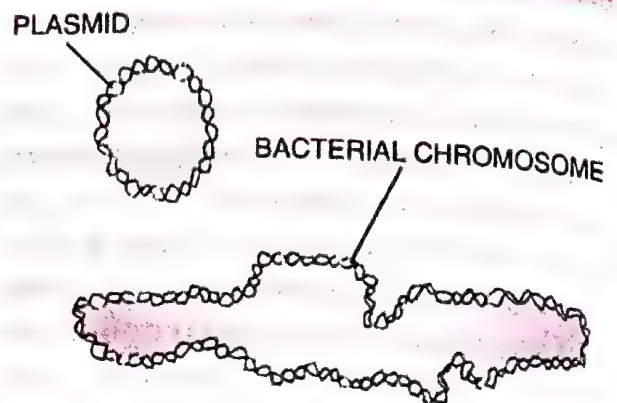


Fig. 11.6. Figures showing plasmid and bacterial chromosome.

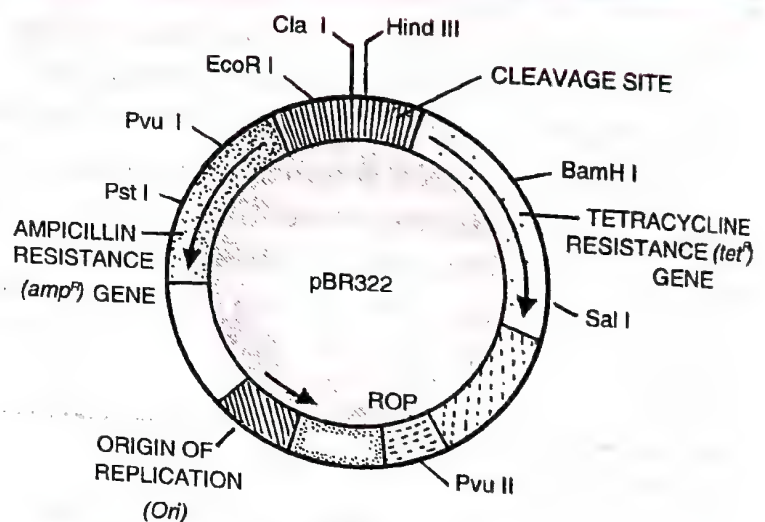


Fig. 11.7. Diagram showing essential features of Plasmid pBR 322.

The presence of restriction sites within the markers tet^R and amp^R permits an easy selection for cells transformed with the recombinant pBR322. Insertion of the DNA fragment into the plasmid using enzyme *Pst* I or *Pvu* I places the DNA insert within the gene amp^R ; this makes amp^R nonfunctional. Bacterial cells containing such a recombinant pBR322 will be unable to grow in the presence of ampicillin, but will grow on tetracycline. Similarly, when restriction enzyme *Bam* HI or *Sal* I is used, the DNA insert is placed within the gene tet^R making it nonfunctional. Bacterial cells possessing such a recombinant pBR322 will, therefore, grow on ampicillin but not on tetracycline.

Due to inactivation of antibiotics, selection of recombinants becomes burdensome process because it requires simultaneous plating on two plates having different antibiotics. Thus, alternative selectable marker is developed to differentiate recombinants and non-recombinants on the basis of their ability to produce colour in the presence of a chromogenic substance. Now a recombinant DNA is inserted in the coding sequence of an enzyme β -galactosidase. This causes inactivation of the enzyme which is called **insertional inactivation**. If the plasmid in the bacterium does not have an insert, the presence of a chromogenic substrate gives blue coloured colonies. Presence of insert results into insertional inactivation of the β -galactosidase and, therefore, the colonies do not produce any colour, these colonies are marked as recombinant colonies.

(iv) **Vectors for Cloning Genes in Plants and Animals.** A soil-inhabiting plant bacterium, *Agrobacterium tumefaciens*, a pathogen (disease causing agent) of several dicot plants is able to transfer a piece of DNA known as 'T-DNA'. The T-DNA causes **tumours**. The tumours are called **crown galls**. Tumour formation is induced by **Ti plasmid** (Ti for tumour inducing). As gene transfer occurs without human effort, the bacterium is called **natural genetic engineer** of plants. Similarly **retroviruses*** (cause leukosis or sarcoma types of cancer) in animals including humans are able to change normal cells into **cancerous** cells. The tumour inducing Ti plasmid of *Agrobacterium tumefaciens* have been modified into cloning vector which is not pathogenic to the plants, however, it is still able to use the procedure to deliver genes of our interest into various plants. Similarly retroviruses are used to carry desirable genes into animal cells. Thus once a gene or DNA fragment is joined to a suitable vector it is transferred into a bacterial plant or animal host where it undergoes multiplication.

(2) **Bacteriophage Vectors.** Bacteriophages (are simply phages) are viruses that attack bacterial cells by injecting their DNA into these cells. The injected DNA is selectively replicated and expressed in the host bacterial cell resulting in a number of phages which burst out of the cell (lytic pathway) and reinfect neighbouring cells. This ability to transfer DNA from the phage genome to specific bacterial hosts during the process of bacterial infection gave scientists the idea that specially designed phage vectors would be useful tools for gene cloning experiments. Several bacteriophages are being used as cloning vectors but most commonly used are lambda (λ) phage and M13 phage.

(a) **Lambda Phage Vector.** It has a double-stranded, linear DNA genome of 48,502bp, in which the 12 bases at each end are unpaired but complementary. These ends are, therefore, sticky or cohesive and are referred to as the cos sites (cohesive end sites). These sites are important for packaging DNA into phage heads. The lambda genome remains linear in the phage head, but within *E. coli* cells the two cohesive ends join to form a circular

*Retrovirus contains reverse transcriptase enzyme which uses viral RNA as template and synthesizes a DNA strand and forms RNA-DNA complex and is transcribed back into RNA. Reverse transcriptase was discovered by Temin (1970). AIDS virus is retrovirus.

molecule necessary for replication. These vectors allow cloning of DNA fragments upto 23 Kb length (= Kilobase— is a unit designating the length of a nucleic acid sequence, e.g., 1 Kb = 1000 nucleotide long base sequence).

(b) **M13 Phage Vector.** It is filamentous phage which infects *E. coli* having F-pili. Its genome is a single stranded, circular DNA of 6407 bp. Foreign DNA can be inserted into it without disrupting any of the essential genes. After the M13 phage DNA enters the bacterial cell, it is converted to a double-stranded molecule known as the **replicative form** or **RF**, which replicates until there are 100 copies in the cell and single-stranded copies of the genome are produced and extruded from the cell as M13 particles. The major advantages of developing vectors based on M13 are that its genome is less than 10Kb length. The RF can be purified and manipulated exactly like a plasmid. In addition, genes cloned in M13 based vectors can be obtained in the form of single-stranded DNA.

Why are bacteriophage vectors more advantageous than plasmid vectors? (i) Bacteriophage vectors can be used for large DNA fragments and (ii) These can easily be detected at the time of cloning experiments.

Some other Cloning Vectors

(1) **Cosmid (= cos + plasmid) Vectors.** The term cosmid is a combination of two words. COS + MID. COS is taken from COS site of Lambda phage and MID is taken from plasmid DNA. Cosmid was developed for the first time by Collins and Hons (1978). Cosmids can be used to clone DNA fragments upto 45 kb in length.

(2) **Bacterial Artificial Chromosome (BAC) Vectors.** These are vectors based on natural, extra-chromosomal plasmid of *E. coli*. These vectors can accommodate upto 300-350 kb of foreign DNA and are also being used in genome sequencing project.

(3) **Yeast Artificial Chromosome (YAC) Vectors.** These are used to clone DNA fragments of more than 1 Mb—Megabase pairs (10^6 bp) in size, therefore, they have been exploited extensively in mapping the large genomes, e.g., in the Human Genome Project. These vectors contain the telomeric sequence, the centromere and the autonomously replicating sequence from yeast chromosomes. They also contain restriction enzyme sites and genes which act as selectable markers in yeast.

(4) **Phagemid Vectors.** Phagemid is a composite structure made of bacteriophage and plasmid. They are used for carrying larger DNA sequences.

(5) **Animal and Plant Viral Vectors.** A vector based on **Simian Virus* 40 (SV40)** was used in the first cloning experiment involving mammalian cells in 1979. Since 1979, a number of vectors based on other types of viruses like **Adenovirus**** and **Papillomavirus***** have been used to clone genes in mammals. At present, retroviral vectors are the most commonly used vectors for cloning genes in mammalian cells. In case of plants, plant viruses like Cauliflower Mosaic Viruses, Tobacco Mosaic Viruses and Gemini Viruses were used but with limited success.

(6) **Transposons as Vectors.** Transposons are units of DNA which can move from one DNA molecule to another hence are said to be mobile. They are also called **transposable elements** or **mobile genes** or **jumping genes**. Transposons were first observed by Clintock (1951) in Maize plants.

(7) **Shuttle vectors.** They can exist in both the eukaryotic cell and *E. coli*. Such vectors are known as **shuttle vectors**. These vectors contain two types of origin of replication and selectable marker genes, one type that functions in the eukaryotic cell and another that functions in *E. coli*. An example of a shuttle is the yeast episomal plasmid YEp. In case of plants, a naturally occurring plasmid of the bacterium *Agrobacterium tumefaciens* called Ti plasmid has been suitably modified to function as a vector. *Most of the eukaryotic vectors are shuttle vectors.*

***Simian Virus 40 (SV 40)** is oncogenic (cancer causing) in new born hamsters — rodents like large rats.

****Adenovirus** can cause diarrhoeal disease in children.

*****Papillomavirus** can cause benign tumours (warts) in humans.

(C) Competent Host (For Transformation with Recombinant DNA)

(a) **DNA Mediated Gene Transfer (Vector Mediated Gene Transfer).** Competent host is essential for transformation with recombinant DNA (Fig. 11.12). Transformation "a process by which a cell takes up naked DNA fragment from the environment, incorporates it into its own chromosomal DNA and finally expresses the trait controlled by the incoming DNA". The tools described earlier in this chapter will result in the generation of recombinant DNA (rDNA) molecules in the laboratory. Finally, the propagation of these DNA molecules must occur inside a living system or a host. Many kinds of host cells, including *E. coli*, yeast, animal and plant cells, are available for genetic engineering and the kind of host cell to be used mainly depends on the aim of the cloning experiment. For the expression of some eukaryotic proteins, eukaryotic cells may be the preferred hosts. Yeasts have been used extensively for functional expression of eukaryotic genes because they offer several advantages. *Yeasts are the simplest eukaryotic organisms and like bacteria are single-celled, genetically well-characterized, easy to grow and manipulate.* They can be grown readily in both small culture vessels and large scale bioreactors. Plant and animal cells may also be used as hosts in gene manipulation experiments and for protein expression either in tissue culture or as cells in the whole organism to create genetically modified plants and animals. Since DNA is a hydrophilic molecule, it can not pass through membranes, so the bacterial cells must be made capable to take up DNA. This is done by treating them with a specific concentration of a divalent cation, such as **Calcium** which increases the efficiency with which DNA enters the bacterium through pores in its cell wall. Recombinant DNA (rDNA) can then be forced into such cells by incubating the cells with recombinant DNA on ice, followed by placing them at 42°C (heat shock), and then putting them back on ice. This enables the bacteria to take up the recombinant DNA.

Transfer of DNA into eukaryotic cell is called **transfection**.

(b) **Direct or Vectorless Gene Transfer.** It is the process of gene transfer into the host cell without using a vector. This is possible by the following four important methods.

1. **Micro-injection.** In this method foreign DNA is directly injected into the nucleus of animal cell or plant cell by using micro needles or micro pipettes. It is used in oocytes, eggs and embryo. **Alec Jeffreys (1993)** of Human Genome Centre, Michigan University U.S.A has cured mice that inherited a neuromuscular disease which is like muscular dystrophy of humans.

2. **Electroporation.** Electroporation is the formation of temporary pores in the plasma membrane of host cells by using **lysozyme** or **calcium chloride**. These pores are used for introduction of foreign DNA.

3. **Chemical Mediated Gene Transfer.** In this method certain chemicals such as **polyethylene glycol (PEG)** help foreign DNA to enter the host cell.

4. **Biolistic Method or Gene gun Method.** Biolistic is a means of introducing DNA into cells that involves bombardment of cells with high-velocity microprojectiles coated with DNA. In biolistic method tungsten or gold particles, coated with foreign DNA are bom-

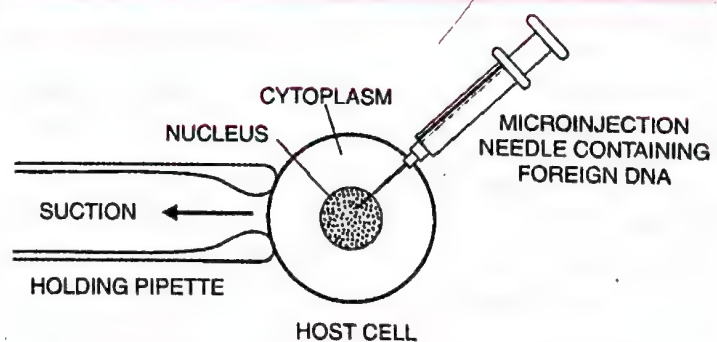


Fig. 11.8. Introduction of foreign DNA in a host cell with a microinjection needle.

barded into target cells at a very high velocity. Although this method is suitable for plants yet this technique is also used to insert genes into animals that promote tissue repair into cells (particular cancer of mouth) near wounds.

This method failed to make an impression in treatment of genetic disorder but made great impact in the field of vaccine development.

After being introduced briefly to the tools in recombinant DNA let us describe the processes to create recombinant DNA.

PROCESSES OF RECOMBINANT DNA TECHNOLOGY

Recombinant DNA (rDNA) technology involves the following stages (Figs. 11.1, 11.2, 11.3 and 11.12)

1. **Isolation of the Genetic Material (DNA).** Nucleic acid (DNA or RNA) is the genetic material of all organisms. It is DNA in majority organisms. For cutting the DNA with restriction enzymes it needs to be pure and free from other macromolecules. Because the DNA is covered by the membranes, it has to break the cell open to release DNA and other macromolecules like RNA, proteins, polysaccharides and lipids. It is obtained by treating the bacterial cells/plant or animal tissue with enzymes such as lysozyme (bacteria), cellulase (plant cells), chitinase (fungus). As we know that genes are present on long molecules of DNA intertwined with proteins like histones, the RNA can be removed by treating with ribonuclease while proteins can be removed by treating with protease. Other molecules are removed by proper treatments. The purified DNA finally precipitates out after the addition of chilled ethanol. This is seen as collection of fine threads in the suspension (Fig. 11.10).

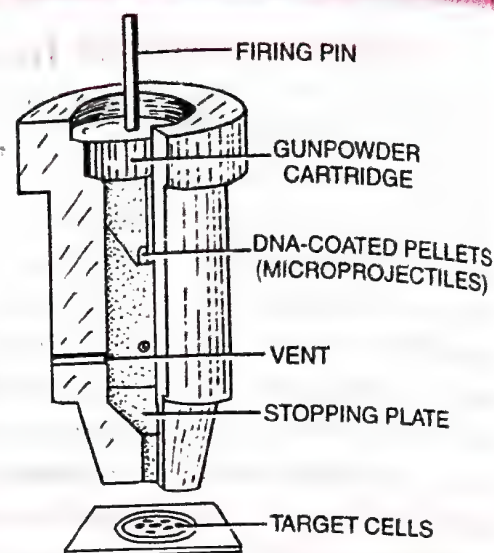


Fig. 11.9. Gene gun.

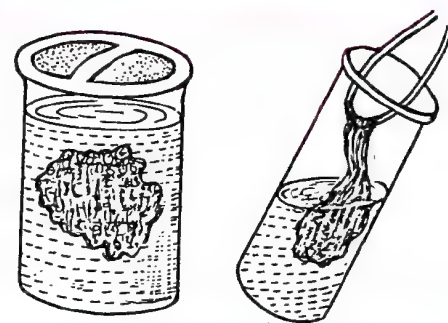


Fig. 11.10. DNA that separates out can be removed by spooling (spool = reel).

2. **Cutting of DNA at Specific Locations.** Under the optimal conditions, the purified DNA is cut by the restriction enzyme. Agarose gel electrophoresis is used to check the progress of a restriction enzyme digestion. Since DNA is a negatively charged molecule, it moves towards the positive electrode (anode). This process is also repeated with the vector.

Formation of Recombinant DNA (rDNA). After the cutting of the source DNA and the vector DNA with a specific restriction enzyme, the cut out 'gene of interest' from the source DNA and the cut vector with space are mixed and ligase enzyme is added. This results in the formation of a rDNA or hybrid DNA or chimeric DNA.

3. **Amplification of Gene of Interest Using PCR** (Fig. 11.11). The Polymerase Chain Reaction or PCR, as it is commonly called, was originally invented by Kary Mullis in 1985. Kary Mullis shared the Nobel Prize with Michael Smith in Chemistry in 1993. *PCR is best defined as the DNA replication in vitro.* It results in the selective amplification of a specific region of a DNA molecule and so can also be used to generate a DNA fragment for cloning. The basic principle underlying this technique is that when a double-stranded DNA molecule

is heated to a high temperature, the two DNA strands separate giving rise to single-stranded DNA molecules. If these single-stranded molecules are copied by a DNA polymerase, it would lead to duplication of the original DNA molecule and if these events are repeated many times, multiple copies of the original DNA sequence can be generated. The basic requirements of a PCR reaction are the following :

(i) **DNA Template.** Any source that contains one or more target DNA molecules to be amplified can be taken as template.

(ii) **Two Nucleotide Primers.** Primers, which are oligo-nucleotides, that hybridize to the target DNA region, one to each strand of the double helix are required. These primers are oriented with their ends facing each other allowing synthesis of the DNA towards one another.

(iii) **Enzyme.** DNA polymerase which is stable at high temperatures ($> 90^{\circ}\text{C}$) is required to carry out the synthesis of new DNA. The DNA polymerase like **Taq polymerase** is generally used in PCR reactions which is isolated from a bacterium *Thermus aquaticus*. Other thermostable (temperature remains stable) polymerases can also be used.

Working Mechanism of PCR (Fig. 11.11). A single PCR amplification cycle involves three basic steps; denaturation, annealing and extension (polymerisation).

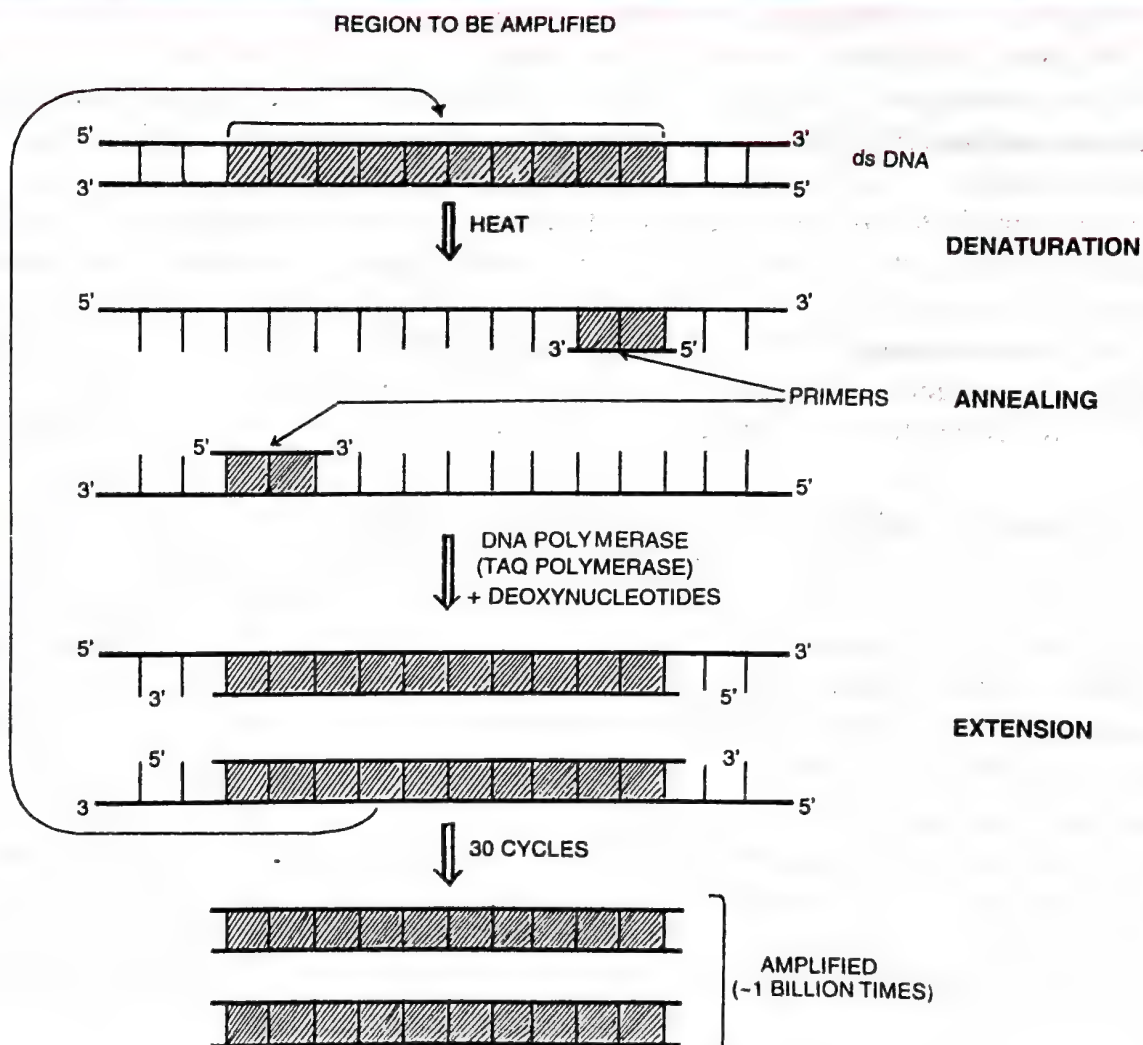


Fig. 11.11. A schematic representation of Polymerase chain reaction (PCR) showing (i) denaturation, (ii) annealing, (iii) extension and (iv) resulting two double stranded DNA fragments that enter the next PCR cycle to be duplicated. **ds DNA** = double stranded DNA, **dNTPs** = deoxynucleotide triphosphates.

(a) **Denaturation (Melting of Target DNA).** In the denaturation step, the target DNA is heated to a high temperature (usually 94° to 96°C), resulting in the separation of the two strands. Each single strand of the target DNA then acts as a template for DNA synthesis.

(b) **Annealing (Anneal = Join).** In this step, the two oligo-nucleotide primers anneal (hybridize) to each of the single stranded template DNA since the sequence of the primers is complementary to the 3' ends of the template DNA. This step is carried out at a lower temperature (usually 40° to 60°C) depending on the length and sequence of the primers.

(c) **Extension (Polymeri-sation).** The final step is extension, wherein *Taq DNA polymerase* (of a thermophilic bacterium *Thermus aquaticus*) synthesizes the DNA region between the primers, using dNTPs (deoxynucleoside triphosphates) and Mg^{2+} . It means the primers are extended towards each other so that the DNA segment lying between the two primers is copied. The optimum temperature for this polymerization step is 72°C .

To begin the second cycle, the DNA is again heated to convert all the newly synthesized DNA into single strands, each of which can now serve as a template for synthesis of more new DNA. Thus the extension product of one cycle can serve as a template for subsequent cycles and each cycle essentially doubles the amount of DNA from the previous cycle.

Application of PCR. Some of the areas of application of PCR are briefly mentioned here.

(i) **Detection of Pathogens.** In recent times, PCR is being used in the detection of HIV (Virus of AIDS). (ii) **Diagnosis of Specific Mutation.** Mutations are related to genetic diseases. By using PCR phenylketonuria, muscular dystrophy, sickle cell anaemia, hepatitis, chlamydia and tuberculosis can be diagnosed. (iii) PCR is also used in **DNA Fingerprinting**. (iv) **Detection of Specific Microorganisms.** In recent years, PCR has also found useful for detecting specific microorganisms. (v) **In Prenatal Diagnosis.** It is useful to detect genetic disease in foetus before birth. (vi) **Diagnosis of Plant Pathogens.** Many diseases of plants can be detected by using PCR. For examples, viroids (associated with apple, grape, citrus, pear, etc.), viruses (like TMV, bean yellow mosaic virus etc), bacteria, mycoplasmas, etc. (vii) **In Palaeontology.** PCR is used to clone the DNA fragments from the mummified remains of humans and extinct animals like woolly mammoth and dinosaurs. (viii) **Gene Therapy.** PCR proves to be of immense help in monitoring a gene in gene therapy experiments.

4. Preparation and Insertion of Recombinant DNA into the Host Cell/Organism (Fig. 11.12). The vector DNA (e.g., plasmid DNA) and alien (foreign) DNA carrying gene of interest are cut by the same restriction endonuclease to produce complementary sticky ends. This process of cutting DNA by restriction enzymes is called **restriction digestion**. With the help of **DNA ligase enzyme**, the complementary sticky ends of the two DNAs are joined (annealing) to produce a recombinant (chimera) DNA (rDNA). The ligase forms new sugar-phosphate bonds to join two DNAs.

Both direct and indirect methods are used to introduce the ligated DNA into the host cells. If a recombinant DNA bearing gene for resistance to antibiotic ampicillin is transferred into *E. coli* cells, the host cells become transformed into ampicillin resistant cells. If such bacteria are transferred on a culture plate containing the antibiotic ampicillin, only the resistant forms will grow and others will die. The ampicillin resistance gene in this case is called a **selective marker**.

5. Obtaining the Foreign Gene Product (Fig. 11.12). When recombinant DNA is transferred into a bacterial, plant or animal cell, the foreign DNA is multiplied. *Most of the recombinant technologies are aimed to produce a desirable protein.* So there is a need for

expression of recombinant DNA. After the cloning of the gene of interest one has to maintain the optimum conditions to induce the expression of the target protein one should consider producing it on a large scale. If any protein encoding gene is expressed in a heterologous host it is known as a “recombinant protein”. The cells having cloned genes of interest can be grown on a small scale in the laboratory. The cultures may be used for extracting and purifying the desired protein. The cells can also be multiplied in a continuous culture system where the used medium is passed out from one side and fresh medium is added from the other side to maintain the cells in their physiologically most active log/exponential phase—rapid multiplication of the cells. This type of culturing method produces a larger biomass to get higher yields of the desired protein.

Bioreactors (Fermenters). Bioreactors are considered as vessels in which raw materials are biologically converted into specific products by microbes, plant and animal cells and/or their enzymes. Small volume cultures cannot give large quantities of the products. Large scale production (100 – 1000 litres) of the products is carried out in bioreactors (Fig. 11.13). A bioreactor provides the optimal conditions for obtaining the desired product by providing optimum growth conditions such as temperature, pH, substrate, vitamins, oxygen and salts.

Types of Bioreactors. The most commonly used bioreactors are of stirring type. Stirring type bioreactors are (i) Simple stirred-tank bioreactor and (ii) Sparged stirred-tank bioreactor as shown in

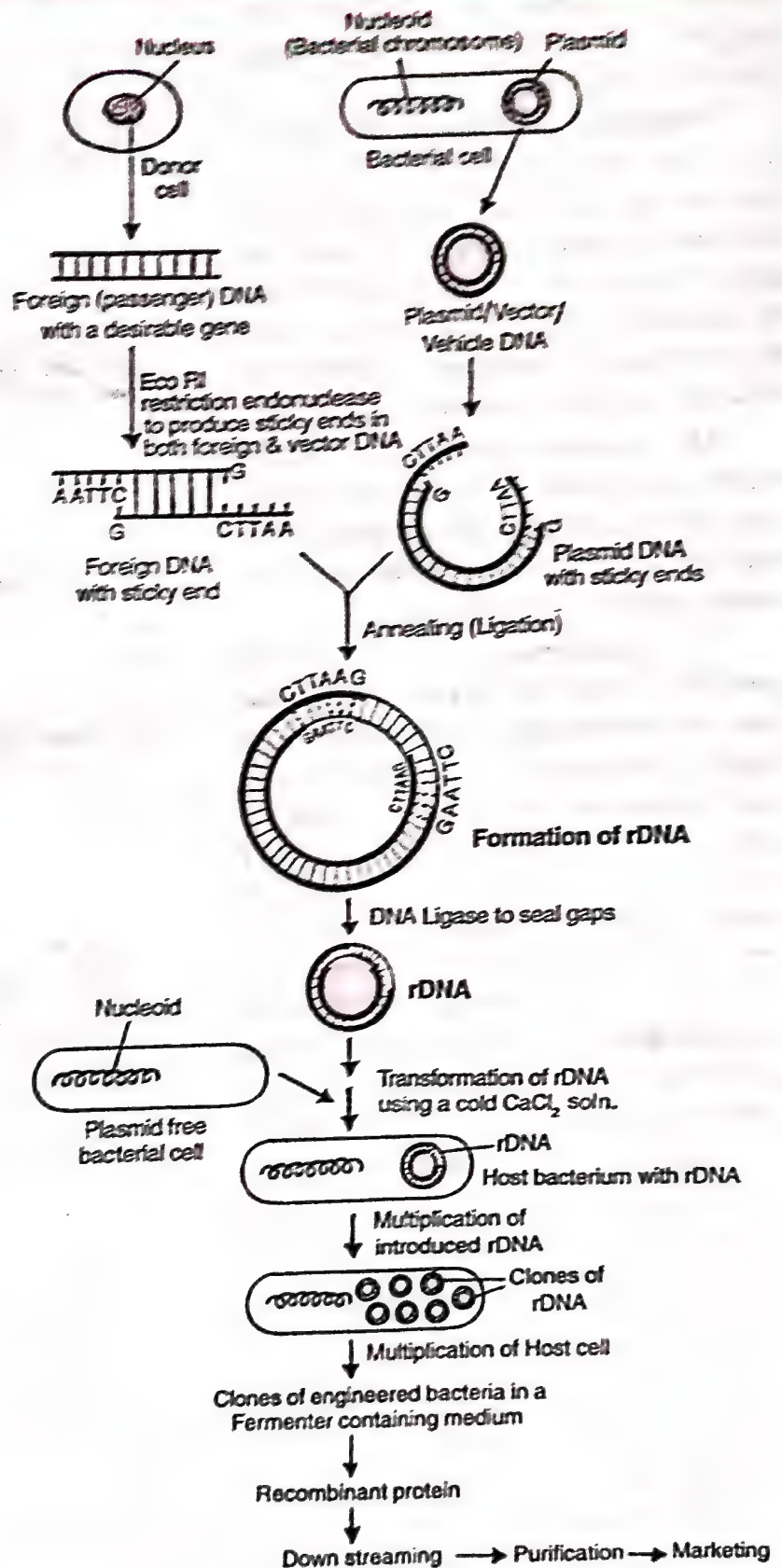


Fig. 11.12. Diagram showing various steps involved in DNA recombinant technology for the production of a recombinant protein.

Fig. 11.13. In the sparged stirred-tank bioreactor, sterile air bubbles are sparged. The surface area for oxygen transfer is increased.

Fermentation Process. Fermentation is the process by which microorganisms turn raw material such as glucose into products such as alcohol. The term fermentation originally applied only to anaerobic processes but is now used more broadly to include all processes whether aerobic or anaerobic.

All operations are carried out under sterile conditions to avoid contamination of the culture. The product is either the cells themselves (biomass) or some useful cell products.

Two basic types of fermentation are possible. These are **batch fermentation** and **continuous fermentation**. In batch fermentation, the nutrients and microorganisms are put in a closed reactor and not changed from outside once the fermentation starts, for example, no more nutrients are added. When nutrients are utilized, the product is separated from microorganisms. In continuous fermentation nutrients are replaced as fast as they are used and products are removed as fast as they are made.

Uses. The stirred-tank bioreactor is well suited for large-scale production of micro-organisms under aseptic conditions for a number of days. It can be used easily in research laboratories. Other advantages are an oxygen delivery system, foam control system, a temperature control system, pH control system, etc.

Drawbacks. Drawbacks in this bioreactor are that it is relatively expensive to run it.

6. Downstream Processing. After the formation of the product in the bioreactors, it undergoes through some processes before a finished product to be ready for marketing. The processes include (a) separation and (b) purification of products which are collectively called the **downstream processing**. The product is subjected to quality control testing and kept in suitable preservatives. If drugs are to be manufactured such formulation has to undergo through clinical trials. A proper quality control testing for each product is also needed. The downstream processing and quality control test are different from product to product.

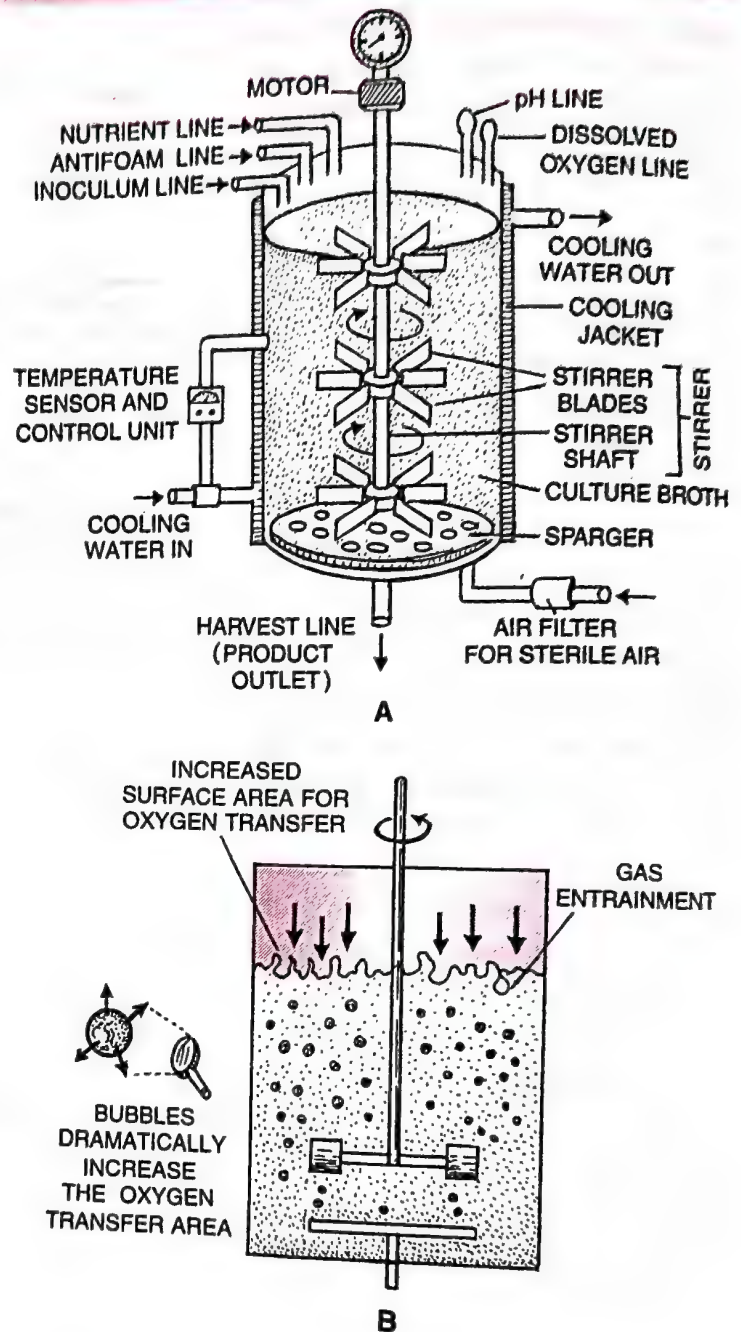


Fig. 11.13. A simple stirred tank bioreactor for continuous culture. B. Sparged-stirred tank bioreactor through which sterile (free from any germs) air bubbles are sparged.

Differences Between Plasmid DNA and Chromosomal DNA

Plasmid DNA	Chromosomal DNA
1. It is always double stranded.	1. It may be single stranded or double stranded.
2. It is circular.	2. It is linear or circular.
3. It is naked without histone protein.	3. It is coated with histone protein.
4. It does not carry any vital gene necessary for cell.	4. It carries vital genes necessary for cell.
5. It can replicate independent of main genome.	5. It replicates with genome.
6. It does not act as genetic factor.	6. It acts as genetic factor.
7. Introns are absent.	7. Both exons and introns are present.

Eukaryotic Vehicles

We have so far described vectors that are suitable for prokaryotic cells especially in *E. coli*. The vehicles (DNAs) are constructed in various ways, but the DNA of Simian virus 40 (SV 40) or its derivative is most commonly used vehicle for mammalian cells. This vehicle can accept an insert of a length of 4.3 Kb and it does not contain any marker.

Passenger DNA/ Foreign DNA/DNA Insert

The DNA which is transferred from one organism into another by joining it with the vehicle DNA, is called passenger or foreign DNA. Generally three types of passenger DNAs are used. These are complementary DNA (cDNA), synthetic DNA (sDNA) and random DNA.

1. **Complementary DNA (cDNA).** It is synthesized on RNA template (usually mRNA) with the help of **reverse transcriptase** enzyme discovered by **Temin and Baltimore** in 1970 and essential nucleotides (Fig 11.14). The DNA is separated from the RNA-DNA complex in the presence of alkaline phosphatase enzyme. A cDNA strand is formed on the separated single-stranded DNA template with the help of DNA polymerase enzyme.

2. **Synthetic DNA (sDNA).** It is synthesized on DNA template or without a template.

Artificial Synthesis of DNA on Template. Kornberg and his coworkers (1959) produced DNA from deoxyribonucleoside triphosphates in the presence of DNA polymerase enzyme, metal ions and a segment of viral DNA which acts as a primer.

Artificial Synthesis of DNA without a Template. Hargobind Khorana and his coworkers in 1970, synthesized the gene which was responsible for coding for tyrosine-tRNA of *E. coli*. The gene had 207 nucleotide pairs.

3. **Random DNA.** Small fragments are formed by breaking a chromosome of an organism in the presence of restriction endonucleases.

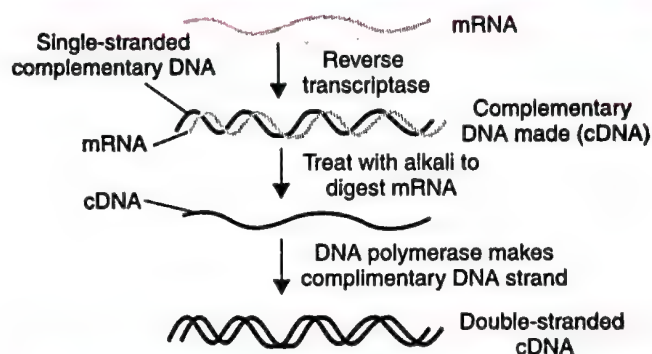


Fig. 11.14. Synthesis of cDNA from RNA.

Difference Between rDNA and cDNA

rDNA	cDNA
It is the DNA formed by joining together DNA from two different organisms.	It is the DNA obtained from an RNA template using the enzyme reverse transcriptase.

Measurement of DNA*

DNA in a cell is measured in terms of DNA content in 1C (G_1 phase of cell cycle) cells or genome size in a haploid cell.

DNA content in a 1C human cells is 3.2 picograms.

DNA size in a haploid human cell is 3.2×10^9 bp**.

Table 11.2. Some of the Recombinant Protein Drugs and their Therapeutic*** Uses.

Recombinant Proteins	Therapeutic Uses
1. OKT-3	Used to prevent acute kidney transplantation rejection. OKT-3 is therapeutic monoclonal antibody.
2. ReoPro	For prevention of blood clots.
3. Tissue Plasminogen activator (t-PA)	Used for acute myocardial infarction as it dissolves blood clot.
4. Asparaginase	For treatment of some types of cancer (particularly Leukemia— blood cancer).
5. DNase	For treatment of cystic fibrosis
6. Human Insulin (Humulin)	For treatment of diabetes mellitus
7. Blood Clotting Factor VIII	For treatment of Haemophilia A
8. Blood Clotting Factor IX	For treatment of Haemophilia B
9. Hepatitis B Vaccine	Prevention of Hepatitis B
10. Platelet growth factor	It stimulates wound healing.
11. Interferon alpha (INF -alpha)	Used as vaccine for Hepatitis C
12. Hirudin	Used as an anticoagulant

ADDITIONAL INFORMATION

- **Molar concentration** is the ratio of the number of moles of solute in a solution divided by the volume of the solution expressed in liters.
- **Dextran** is a polysaccharide produced by certain bacteria and is used in blood transfusions.
- New weeds, insects pests and diseases

could also come into our country alongwith the introduced varieties, e.g., *Argemone mexicana*. Therefore, all introductions are carefully examined for the presence of weeds, insects and disease-causing organisms; this is known as **quarantine**.

- Humans have produced a new allopolyploid crop called **Triticale** in the following

*Ref. "Genome maps " By O'Brion

**bp means base pair.

***Therapeutic – pertaining to the treating or curing of a disease.

manner. Allotetraploid wheat (*Triticum turgidum*) was hybridised with rye (*Secale cereale*; a diploid species). The chromosome number of the resulting F_1 was doubled to produce triticale. Triticale is cultivated in some areas of Punjab and in the hilly regions of the country.

- **Gene splicing or Isolation of DNA.** Following are some techniques to isolate or synthesise the gene or the DNA fragment. (i) Fragmentation of DNA by cleaving with restriction enzymes. (ii) Artificial synthesis of gene. (iii) Synthesis of complementary DNA (cDNA).
- The most popular eukaryotic host organism is **yeast** specially *Saccharomyces cerevisiae* (**baker's yeast**).
- In 1982 Government of India set up the **National Biotechnology Board (NBTB)**. In 1986 NBTB was replaced with a full-fledged department, the **Department of Biotechnology (DBT)** within the ministry of Science and Technology.
- The process of producing genetically similar molecules, cells or organisms from a single parent by asexual reproduction *in vitro* or *in vivo** is called **cloning**. The most famous clone of the world is **Dolly**, a sheep, died recently.
- **GEAC** – Genetic Engineering Approval Committee is an organisation set up by the Indian Government. This will make decisions regarding (i) the validity of GM research and

(ii) the safety of introducing genetically modified organisms (GMO) for public services.

- Eukaryotes do not have restriction enzymes.
- **Teminism** is reverse transcription which was discovered by Temin and Baltimore in 1970.
- Hepatitis B virus vaccine was the first recombinant DNA based product produced and marketed in India.
- **Har Gobind Khorana** developed method of chemical synthesis of gene.
- **Topoisomerase enzymes** break and reseal strands of DNA which serve as starting points for replication.
- Prof. V.L. Chopra is considered the **father of biotechnology in India**.
- **Molecular probes** are small DNA or RNA segments that are used to detect the presence of complementary sequences in DNA or RNA molecules and thus allow identification and isolation of these specific DNA or RNA sequences from an organism.
- **Molecular Marker.** It is a fragment of the DNA molecule that is associated with certain trait(s) in an organism. Markers help us in determining the location (map position) of genes that control important traits.
- **Repeated DNA Sequence.** A sequence of nucleotides which occurs more than once in a genome.
- **Ri Plasmids.** A plasmid of *Agrobacterium rhizogenes* which induces quick rooting in host organisms after infection.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. Can you list 10 recombinant proteins which are used in medical practice ? Find out where they are used as therapeutics; (use internet).
✓ Refer to the text table 11.2 Important Recombinant Proteins and their Therapeutic uses.
2. Make a chart (with diagrammatic representation) showing a restriction enzyme, the substrate DNA on which it acts, the site at which it cuts DNA and the product it produces.
✓ Refer to the text Fig. 11.13 Diagram showing various steps Involved in DNA Recombinant Technology for the Production of Recombinant Protein.
3. From what you have learnt, can you tell whether enzymes are bigger or DNA is bigger in molecular size ? How did you know ?
✓ DNA molecules are bigger in molecular size as compared to molecular size of enzymes. The enzymes are proteins. Protein synthesis is regulated by small portions of DNA, called genes.
4. What would be the molar concentration of human DNA in a human cell ? Consult your teacher.
✓ DNA content in a 1C human cell is 3.2 picograms.
5. Do eukaryotic cells have restriction endonucleases ? Why
✓ No, the eukaryotic cells do not have restriction endonucleases. All the restriction endonucleases have been isolated from various strain of bacteria. Prokaryotes/bacteria have this enzyme as a defence mechanism to restrict the growth of bacteriophages.

**In vitro* – outside the living organism. *In vivo* – within the living organism.

6. Besides better aeration and mixing properties, what other advantages do stirred tank bioreactors have over shake flasks ?

✓ Besides better aeration and mixing properties, the bioreactors have following advantages (i) Small volumes of cultures are periodically withdrawn from the reactors for sampling. (ii) They have a foam control system. (iii) They have temperature and pH control systems. (iv) They have system of sterilisation.

7. Collect five examples of palindromic DNA sequences by consulting your teacher. Better try to create a palindromic sequence by following base pair rules.

✓ Palindromic nucleotide sequences in the DNA molecule are groups of bases that form the same sequence when read both forward and backward. Five examples of palindromic DNA sequences are as follows :

(1) 5' ——— A C T A G T ——— 3'
3' ——— T G A T C A ——— 5'

(2) 5' ——— A A G C T T ——— 3'
3' ——— T T C G A A ——— 5'

(3) 5' ——— G G A T C C ——— 3'
3' ——— C C T A G G ——— 5'

(4) 5' ——— A G G C C T ——— 3'
3' ——— T C C G G A ——— 5'

(5) 5' ——— A C G C G T ——— 3'
3' ——— T G C G C A ——— 5'

8. Can you recall meiosis and indicate at what stage a recombinant DNA is made ?

✓ A recombinant DNA is made in first meiotic prophase by the process of crossing-over in the pachytene stage.

9. Can you think and answer how a reporter enzyme can be used to monitor transformation of host cells by foreign DNA in addition to a selectable marker ?

✓ A reporter enzyme can be used to differentiate transformed cells by tracking down the activity of its co-responding genes (receptor gene). For e.g., β -galactosidase (Lac Z) activity is not found in transformed cells so that they appear white in colour. The others, which appear blue in colour, indicate that cells do not carry foreign DNA.

10. Describe briefly the followings :

(a) origin of replication (b) bioreactors (c) downstream processing.

✓ (a) **Origin of Replication (Ori)** is a sequence from where replication starts and any piece of foreign DNA is linked to this sequence. The replication occurs inside the host cells. This new sequence is also responsible for controlling copy number of linked DNA. Therefore, if any person wants to produce many copies of the target DNA he/she should clone in a vector whose origin gives support to high copy number.

(b) Small volume cultures cannot give large quantities of the products. To produce large quantities of these products development of "**bioreactors**" was required where large volumes (100-1000 litres) of culture can be processed. Hence, bioreactors are like vessels in which raw materials are biologically converted into specific products, individual enzymes or using microbial, plant, animal or human cells. A bioreactor provides the optimal conditions for obtaining the desired product by providing optimum growth conditions such as substrate, temperature, pH, vitamins, oxygen and salts. One of the most commonly used bioreactor is of stirring type

(c) After the formation of the product, it undergoes through some processes before a finished product is ready for marketing. The processes include separation and purification which are collectively called the **downstream** processing. The product is kept in suitable preservatives. If drugs are to be manufactured such formulation has to undergo through clinical trials. A proper quality control testing for each product is also needed. The downstream process and quality control test are different from product to product.

11. Explain briefly (a) PCR (b) Restriction enzymes and DNA (c) Chitinase.

✓ (a) PCR stands for polymerase chain reaction. In this reaction, multiple copies of the gene of interest are synthesized *in vitro* under three steps :

- (i) **Denaturation.** In this, double stranded DNA is converted to the single stranded often achieved by heating or alkaline conditions. This is called "melting" of DNA.
- (ii) **Annealing.** The two sets of primers (small chemical synthesized oligonucleotides that are complementary to the regions of DNA) undergo biochemical process of annealing at an optimum temperature of 40-65° C.
- (iii) **Extension.** The enzyme DNA polymerase extends the primers using the nucleotides provided in the reaction and the genomic DNA as template.

If the process of replication of DNA is repeated many times, the segment of DNA can be amplified to approximately billion times. Such repeated amplification is achieved by the use of a thermostable DNA polymerase and the amplified fragment if desired can be used to ligate with a vector for further cloning.

(b) Two enzymes responsible for restricting the growth of bacteriophage in *E.coli* were isolated. One of these added methyl groups to DNA while the other cut DNA. The later was called restriction endonuclease. The restriction endonuclease binds to the DNA and cuts each of the two strands of the double helix at specific points in their sugar-phosphate backbones.

(c) During the isolation of DNA in processes of recombinant DNA technology, the fungal cell is heated with enzyme called **chitinase**. The chitinase enzyme dissolves the chitin membrane of the fungus to open the cell for release of DNA along with other macromolecules such as RNA, proteins, polysaccharides and lipids.

12. Discuss with your teacher and find out how to distinguish between (a) Plasmid DNA and Chromosomal DNA (b) RNA and DNA (c) Exonuclease and Endonuclease.

✓ (a) **Plasmid DNA** is naked double stranded DNA that forms a circle with no free ends. It is associated with few protein but contains RNA polymerase enzyme. They are smaller than the host chromosome and can be easily separated.

Chromosomal DNA is double stranded linear DNA molecular associated with large proteins. This DNA exists in relaxed and supercoiled forms and provides a template for replication and transcription. It has free ends represented as 3' -5'.

(b) RNA

- (i) The sugar in RNA is ribose.
- (ii) The nitrogenous bases in RNA are Adenine, guanine, cytosine and uracil.
- (iii) It is found in the cytoplasm.
- (iv) It is of three types — rRNA, mRNA, and tRNA.
- (v) It is single stranded and not helically coiled.

DNA

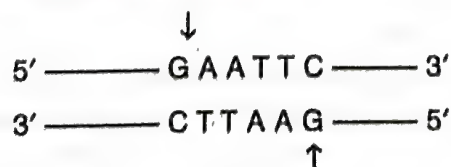
- (i) The sugar in DNA is deoxyribose.
- (ii) The nitrogenous bases in DNA are Adenine, guanine, cytosine and thymine.
- (iii) It is found in the chromosome of the nucleus.
- (iv) It is of one type.
- (v) It is double stranded and helically coiled.

- (c) **Exonucleases** are nucleases which cut off nucleotides from 5' or 3' ends of DNA molecule. **Endonucleases** are nucleases which cleave DNA duplex at any point except the ends.

TEXT QUESTIONS

One Mark Questions (With Answers)

1. Name the enzyme responsible for cleavage in the following sequence :



✓ Type II restriction enzyme obtained from *Escherichia coli*, called Eco RI.

2. Name a 'natural genetic engineer' of plants.

✓ *Agrobacterium tumefaciens*, a crown gall bacterium, is called natural genetic engineer of plants.

3. What would be DNA size in a haploid human cell ?
✓ 3.2×10^9 bp.
4. What are palindromic nucleotide sequences ?
✓ These are groups of nucleotides that form the same words when read both forward and backward.
For example

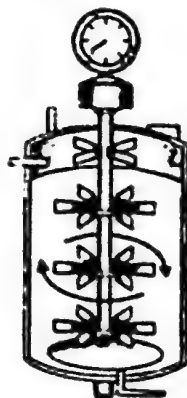
$$\begin{array}{c} 5' \text{ ————— G A A T T C ————— } 3' \\ 3' \text{ ————— C T T A A G ————— } 5' \end{array}$$
5. Which enzymes are used for releasing macromolecules (DNA) from cell envelope ?
✓ Lysozyme for bacteria, cellulase for plant cell and chitinase for fungus.
6. Which enzymes are called molecular scissors ?
✓ Restriction endonucleases.
7. Expand abbreviation EFB.
✓ European Federation of Biotechnology.
8. How many types of restriction endonucleases are found ?
✓ Three types namely Type I, Type II and Type III.
9. Which type of restriction endonucleases take part in recombinant DNA technology ?
✓ Type II.
10. Which cloning vector was discovered for the first time ?
✓ Cloning vector pBR322
11. Name the scientists who generated first recombinant DNA molecules.
✓ The first recombinant DNA molecules were generated in 1972 by Paul Berg, Herbert Boyer, Annie Chang and Stanley Cohen.
12. Name the bacterium that yields a thermostable DNA polymerase.
✓ *Thermus aquaticus*.
13. What is main function of gel electrophoresis ?
✓ It is to separate the fragments of DNA.
14. Name the pathogen that transforms normal plant cell into a tumor.
✓ *Agrobacterium tumefaciens*.
15. What is the main function of bioreactors ?
✓ It is to produce vaccines, enzymes, hormones and monoclonal antibodies on large scale cell cultures.
16. What is particle gun ?
✓ Particle gun is a technique of bombarding micro-particles of gold or tungsten coated with foreign DNA with great velocity into the target cells.
17. What is teminism ?
✓ It is reverse transcription.
18. What is the best method for separation of DNA fragments ?
✓ Agarose gel electrophoresis.
19. What are the two sets of primers needed for amplification of gene ?
✓ (i) Chemically synthesised short segments of DNA (oligonucleotides) (ii) Enzyme DNA polymerase.
20. Name an eukaryotic organism that has plasmids, and can be used as a host in gene cloning experiments.
✓ Yeast.
21. What is elution in the process of separation of DNA fragments ?
✓ **Elution** is the process in which the separated bands of DNA are cut from the gel and DNA extracted from the gel pieces.
22. What was the first recombinant DNA based product, produced and marketed in India ?
✓ Hepatitis B virus vaccine.
23. Who discovered DNA polymerase enzyme ?
✓ DNA polymerase was discovered by **Arthur Kornberg**.
24. Name the enzyme that prevents sealing or joining of the cohesive cleaved ends of vector.
✓ Alkaline phosphatase digests the 5' -phosphate group from 5' end of vector. This prevents formation of phosphodiester bond between 3' and 5' ends of the vector and thus prevents sealing act.
25. Name two vectors which can clone largest amount of foreign DNA.
✓ 1. Bacterial artificial chromosome (BAC) vectors and 2. Yeast artificial chromosome (YAC) vectors.

26. What chemical is used in vectorless gene transfer ?
✓ Polyethylene glycol helps in transfer of foreign DNA into the host cell.
27. What is inoculum line in a bioreactor ?
✓ Microorganisms can be added through inoculum line in the bioreactor.
28. What is the advantage of sparged stirred-tank bioreactor ?
✓ In the sparged stirred tank, the stirrer facilitates the mixing and oxygen availability throughout the bioreactor.
29. Why is a thermostable DNA polymerase needed in amplification/genetic engineering ?
✓ It remains active during high temperature used to denature the double stranded DNA.
30. Name the compound used for staining the isolated DNA in the gel.
✓ Ethidium bromide.
31. What is 'ori' ?
✓ Ori refers to the specific DNA sequence where replication is initiated.
32. How can bacterial DNA be released from the bacterial cell for biotechnology experiments ?
(CBSE 2011)
33. (a) State the role of DNA ligase in biotechnology.
(CBSE 2012)
34. Draw a schematic sketch of pBR 322 plasmid and label the following in it :
(a) Any two restriction sites.
(b) Ori and rop genes.
(c) An antibiotic resistant gene.
(CBSE 2012)
35. Explain with the help of a suitable example the naming of a restriction endonuclease. (CBSE 2014)

Two Mark Questions (With Sample Answers)

1. What are selectable 'marker's' ? What is their use in genetic engineering ?
✓ The selectable marker is the sequence on DNA, which helps in identifying and eliminating non-transformants and selectively permitting the growth of transformants. The vector requires a selectable marker for this purpose.
2. What were the two main discoveries that led to the birth of genetic engineering ?
✓ (a) Discovery of restriction enzymes : These enzymes cut DNA into short pieces containing identifiable genes at specific sites. For example, Eco RI cut DNA at the sequence GAATTC/CTTAAG in double helical DNA.
(b) Presence of plasmid in bacteria
3. How is the gene z (for β galactosidase) used as a marker ?
✓ A recombinant DNA is inserted within the coding sequence of β -galactosidase ; this results into activation of the enzyme (called insertional inactivation). It is treated with a chromogenic substance. If the plasmid in the bacteria have an insert blue colour appears, if they do not produce blue colour, they are recombinants.
4. What are the functions of the enzymes isolated by Stewart Linn and Werner Arber ?
✓ The enzymes were responsible for restricting the growth of bacteriophage. One of them modification enzyme added methyl groups to the DNA. The second one, restriction endonuclease cut the DNA into segments.
5. What essential features must be present in a cloning vehicle?
✓ An ideal cloning vehicle must possess the following features. (i) It should contain an origin of replication (Ori) (ii) It should incorporate a selective marker, which helps in identifying and eliminating non-transformants. (iii) The vector must also have atleast one unique restriction endonuclease recognition site. (iv) It should be relatively small.
6. How are restriction enzymes different from the topoisomerases functionally ?
✓ **Restriction enzymes** are nucleases which cut DNA into short pieces containing identifiable genes at specific sites. These pieces are then introduced into plasmids, yeasts or plant cells. **Topoisomerase** enzymes break and reseal strands of DNA which serve as starting points for replication.
7. What is the major difference between simple stirred tank bioreactor and sparged stirred tank bioreactor? What is its advantage?
✓ Sterile air bubbles are sparged into the sparged stirred-tank bioreactor. The surface area for oxygen transfer is increased.

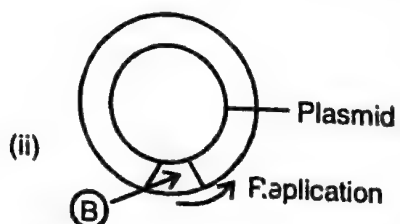
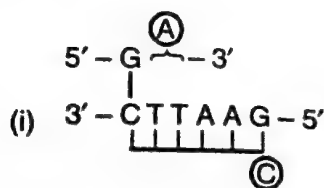
8. How is DNA isolated from prokaryotic and eukaryotic cells ?
 ✓ (i) In prokaryotes, the bacterial cells are treated with certain lysozymes to break the cell wall. (ii) In eukaryotes plant cell wall can be removed by treatment with cellulase ; in case of fungi, it can be removed by treatment with chitinase.
Common steps of prokaryotes and eukaryotes :
 After the boundary is broken, the nucleic acid (along with other compounds) is released from the cell. The DNA exists with certain proteins and RNA; so they have to be removed. Proteins are removed by treatment with proteases and RNA by treatment with ribonuclease. Other molecules are removed by appropriate treatment. Then DNA is precipitated out after the addition of chilled ethanol.
9. Enlist two core techniques that have enabled birth of modern biotechnology.
 ✓ (i) **Genetic engineering.** This technique refers to change in the genetic material and its introduction into host organisms for changing the phenotype of the host organism.
 (ii) **Chemical engineering.** It involves maintenance of sterile medium so as to enable the growth of only the desired microbes in large quantities for the manufacture of biotechnological products like antibiotics, vaccines and enzymes etc.
10. List the key tools used in recombinant DNA technology. (CBSE 2011)
11. Name the type of bioreactor shown. Write the purpose for which it is used. (CBSE 2011)



12. How is the amplification of gene sample of interest carried out using polymerase chain reaction (PCR)? (CBSE 2012)
13. Expand the following and mention one application of each : (i) PCR ; (ii) ELISA. (CBSE 2013)
14. (a) Mention the difference in the mode of action of exonuclease and endonuclease.
 (b) How does restriction endonuclease function. (CBSE 2013)
15. Name the source of the DNA polymerase used in PCR technique. Mention why it is used. (CBSE 2013)
16. Write any four ways used to introduce a desired DNA segment into a bacterial cell in recombinant technology experiments. (CBSE 2013)

Three Mark Questions

1. What is down stream processing in respect of biotechnology ?
2. (a) Identify (A) and (B) illustrations in the following : (CBSE 2011)



- (b) Write the term given to (A) and (C) and why ?
- (c) Expand PCR. Mention its importance in biotechnology.
3. Explain the work carried out by Cohen and Boyer that contributed immensely in biotechnology. (CBSE 2012)

4. (a) Name the selectable markers in the cloning vector pBR322 ? Mention the role they play.
(b) Why is the coding sequence of an enzyme β -galactosidase a preferred selectable marker in comparison to the ones named above ? (CBSE 2016)
5. (a) Why must a cell be made 'competent' in biotechnology experiments ? How does calcium ion help in doing so ?
(b) State the role of 'biolistic gun' in biotechnology experiments. (CBSE 2016)
6. (a) Explain the significance of palindromic nucleotide sequences in the formation of recombinant DNA.
(b) Write the use of restriction endonuclease in the above process. (CBSE 2017)
7. Describe the roles of heat, primers and the bacterium *Thermus aquaticus* in the process of PCR. (CBSE 2017)
8. Explain the role(s) of the following in Biotechnology.
 - (a) Restriction endonuclease
 - (b) Gel-electrophoresis
 - (c) Selectable markers in pBR322. (CBSE 2017)

Five Mark Questions

1. (a) Illustrate the recognition sequence of EcoRI and mention what such sequences are called.
(b) How does restriction endonuclease act on a DNA molecule ? (CBSE 2010)
2. Any recombinant DNA with a desired gene is required in billion copies for commercial use. How is the amplification done ? Explain. (CBSE 2010)
3. Name the GM bacterium whose product is used as a clot buster. Name the product. Specify its use in medical science. (CBSE 2010)
4. (i) Describe the characteristics a cloning vector must possess.
(ii) Why DNA cannot pass through the cell membrane ? Explain. How is a bacterial cell made "competent" to take up recombinant DNA from the medium ? (CBSE 2011)
5. (a) With the help of diagrams show the different steps in the formation of recombinant DNA by action of restriction endonuclease enzyme EcoRI.
(b) Name the technique that is used for separating the fragments of DNA cut by restriction endonucleases. (CBSE 2011)
6. How is the amplification of a gene sample of interest carried out using Polymerase Chain Reaction (PCR) ? (CBSE 2012)
7. (a) Explain how to find whether an *E. coli* bacterium has transformed or not when a recombinant DNA bearing ampicillin resistant gene is transferred into it.
(b) What does the ampicillin resistant gene act as in the above case ? (CBSE 2013)

Value Based Questions (With Answers)

1. Sohan introduced his friend Ravi to his father and told that Ravi is doing M.Sc. Biotechnology. Ravi's father had never heard this term. He wanted to know about this term.
Read the above passage and answer the following questions :
 - (i) What is biotechnology ?
 - (ii) Why was Sohan's father eager to know about biotechnology?
 - (iii) Who coined this term ?
 - ✓ (i) Biotechnology deals with techniques of using live micro-organisms, plant or animal cells or their components or enzymes from organisms to produce products and processes (serves) useful to human beings.
 - (ii) To know the latest developments in science.
 - (iii) Karl Ereky coined the term biotechnology in 1917.
2. John heard about "Dolly" as cloned sheep. He asked about it with his biology teacher.
Read the above passage and answer the following questions.
 - (i) What are clones ?
 - (ii) How are clones produced in plants ?

(iii) Is 'Dolly' living now-a-days ?

- ✓ (i) Clones are identical copies of an organism produced by biotechnological methods.
- (ii) In plants, clones are produced by clonal propagation using tissue culture technique.
- (iii) 'Dolly' is no more now-a-days.

3. Ramesh went to a laboratory to get a test of malaria done. He saw there that it was written that PCR test was also done here. He became curious to know about PCR.

Read the above passage and answer the following questions.

(i) What is PCR ?

(ii) Who invented it ?

(iii) Pathogen of which disease is best detected by PCR ?

- ✓ (i) The Polymerase Chain Reaction (PCR) is best defined as the DNA replication *in vitro*.
- (ii) Kary Mullis in 1985.
- (iii) HIV (Virus of AIDS)

4. Rani requested her teacher to tell the therapeutic uses of recombinant proteins (i) OKT-3, (ii) Tissue Plasminogen activator (t-PA), (iii) Blood Clotting Factor VIII, (iv) Platelet growth factor.

- ✓ (i) used to prevent acute kidney transplantation rejection.
- (ii) used for acute myocardial infarction as it dissolves blood clot.
- (iii) For treatment of Haemophilia A.
- (iv) It stimulates wound healing.

Multiple Choice Questions (With Answers)

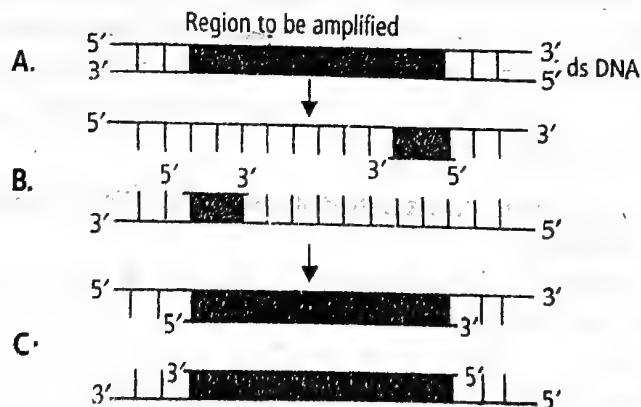
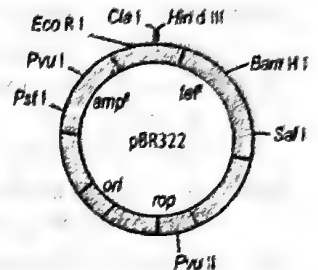
- (1) In recombinant DNA technique the term vector refers to (a) plasmids that can transfer foreign DNA into a living cell (b) cosmids that can cut DNA at specific base sequence (c) plasmids that can join different DNA fragments (d) cosmids that can degrade harmful proteins. (Orissa JEE 2010)
- (2) Insect tolerant gene from *Bacillus thuringiensis* is introduced using Ti plasmid of (a) *Escherichia coli* (b) *Haemophilus influenzae* (c) *Agrobacterium tumefaciens* (d) *Arabidopsis thaliana*. (AMU 2010)
- (3) The source of *Taq* polymerase used in PCR is a (a) thermophilic fungus (b) mesophilic fungus (c) thermophilic bacterium (d) halophilic bacterium. (DUMET 2010)
- (4) The vector for T-DNA is (a) *Thermus aquaticus* (b) *Salmonella typhimurium* (c) *Agrobacterium tumefaciens* (d) *Escherichia coli* (e) *Bacillus thuringiensis*. (Kerala PMT 2010)
- (5) GAATTC is the recognition site for which of the following restriction endonuclease (a) *Hind* III (b) *Eco* RI (c) *Bam* I (d) *Hae* III. (Orissa JEE 2010)
- (6) Give below is a sample of a portion of DNA strand giving the base sequence on the opposite strands. What is so special shown in it ?

5' _____ GAATTC' _____ 3'
3' _____ CTTAAG _____ 5'

- (a) replication completed (b) deletion mutation (c) start codon at the 5' end (d) palindromic sequence of base pairs.
- (7) There is a restriction endonuclease called *Eco* RI. What does "co" part in it stand for ? (a) Colon (b) Coelom (c) Coenzyme (d) Coli. (AIPMT (Prelims) 2011)
- (8) Agrose extracted from sea weeds is used in (a) spectrophotometry (b) tissue culture (c) PCR (d) gel electrophoresis. (AIPMT (Prelims) 2011)
- (9) Silencing of mRNA has been used in producing transgenic plants resistant to (a) bollworms (b) nematodes (c) white rusts (d) bacterial blights. (AIPMT (Prelims) 2011)
- (10) Restriction enzymes are used to cut (a) single stranded RNA (b) double stranded DNA (c) single stranded DNA (d) double stranded RNA. (AIPMT (Mains) 2011)
- (11) In the PCR technology the DNA segment is replicated over a billion times. This repeated replication is catalyzed by the enzyme. (a) DNA polymerase (b) *Taq* polymerase (c) DNA dependent RNA polymerase (d) Primase. (West Bengal JEE 2011)
- (12) Plasmids are (a) extra chromosomal DNA which can self replicate (b) DNA carrying genetic sequence, without expressing it (c) integrated within host DNA without replication ability (d) none of these. (AMU (Medical) 2011)
- (13) cDNA is (a) formed by reverse transcriptase (b) cloned DNA (c) circular DNA (d) recombinant DNA. (Orissa JEE 2011)

(Orissa JEE 2011)

- (14) First transgenic plant released for commercial use was
(a) Bt-cotton (b) tobacco (c) golden rice (d) solan gola.
- (15) DNA polymerase can be obtained from
(a) pBR 322 (b) *Thermus aquaticus* (c) *Agrobacterium* (d) Retrovirus.
- (16) Which one of the following is a case of wrong matching ?
(a) Somatic hybridization — Fusion of two diverse cells.
(b) Vector DNA — Site for tRNA synthesis.
(c) Micropropagation — *in vitro* production of plants in large numbers.
(d) Callus — Unorganised mass of cells. (CBSE PMT (Prelims) 2012)
- (17) The given figure is the diagrammatic representation of the *E. coli* vector pBR 322. Which one of the given options correctly identifies its certain component(s)?
(a) *ori* - original restriction enzyme (b) *rop* - reduced osmotic pressure
(c) *Hin d III*, *Eco R I* - selectable markers (d) *amp^r*, *tet^r* - antibiotic resistance genes. (CBSE PMT Prelims 2012)
- (18) Biolistics (gene - gun) is suitable for (a) disarming pathogen vectors
(b) transformation of plant cells (c) constructing recombinant DNA by joining with vectors (d) DNA finger printing. (CBSE PMT Mains 2012)
- (19) DNA parts which can switch their positions are (a) cistrons (b) transposons (c) introns (d) none of these. (Odisha JEE 2012)
- (20) In a genetic engineering experiment, restriction enzymes can be used for (a) bacterial DNA only
(b) viral DNA only (c) any DNA fragment (d) eukaryotic DNA only. (J & K CET 2012)
- (21) The usual source of restriction endonucleases used in gene cloning is (a) fungi (b) bacteria (c) plants
(d) viruses. (West Bengal JEE 2012)
- (22) Restriction enzyme *Eco RI* cuts the DNA between bases G and A only when the sequence in DNA is (a) GATATC (b) GAATTC (c) GATTCC (d) GAACTT. (AMU 2012)
- (23) The figure below shows three steps (A, B, C) of Polymerase Chain Reaction (PCR). Select the option giving correct identification together with what it represents ?



- (a) B - denaturation at a temperature of about 98°C separating the two DNA strands.
(b) A - denaturation at a temperature of about 50°C
(c) C - extension in the presence of heat stable DNA polymerase.
(d) A - annealing with two sets of primers. (CBSE PMT Mains 2012)
- (24) _____ is a globular protein of ~6 kDa consisting of 51 amino acids, arranged in 2 polypeptide chains held together by disulphide bridge. (a) Insulin (b) Keratin (c) Glucagon (d) Fibrinogen. (AMU 2012)
- (25) Which one is a true statement regarding DNA polymerase used in PCR (a) it is used to ligate introduced DNA in recipient cell (b) it serves as a selectable marker (c) it is isolated from a virus
(d) it remains active at high temperature. (CBSE PMT Prelims 2012)
- (26) *Eco RI* cleaves the DNA strands to produce
(a) blunt ends (b) sticky ends (c) satellite ends (d) *ori* replication end. (Karnataka CET 2013)
- (27) Match the entries in Column-I with those of Column-II and choose the correct answer.

Column – I

Column – II

(A) Restriction endonucleases

(p) Kohler and Milstein

(B) Polymerase Chain reaction

(q) Alec Jeffreys

(C) DNA fingerprinting

(r) Arber

(D) Monoclonal antibodies

(s) Kary Mullis

(a) A – (r), B – (s), C – (q), D – (p) ; (b) A – (r), B – (q), C – (s), D – (p)

(c) A – (q), B – (r), C – (s), D – (p) ; (d) A – (q), B – (s), C – (r), D – (q) (Karnataka CET 2013)

- (28) DNA fragments generated by the restriction endonucleases in a chemical reaction can be separated by (a) electrophoresis (b) restriction mapping (c) centrifugation (d) polymerase chain reaction.

(NEET 2013)

- (29) The taq polymerase enzyme is obtained from (a) *Thiobacillus ferrooxidans* (b) *Bacillus subtilis* (c) *Pseudomonas putida* (d) *Thermus aquaticus*. (NEET-I-2016)

- (30) Stirred-tank bioreactors have been designed for (a) purification of product (b) addition of preservatives to the product (c) availability of oxygen throughout the process (d) ensuring anaerobic conditions in the culture vessel. (NEET-II-2016)

- (31) A foreign DNA and plasmid cut by the same restriction endonuclease can be joined to form a recombinant plasmid using (a) *Eco* RI (b) taq polymerase (c) polymerase III (d) ligase. (NEET-II-2016)

- (32) Which of the following is not a component of downstream processing ?

(a) Separation (b) Purification (c) Preservation (d) Expression.

(NEET-II-2016)

- (33) What is the criterion for DNA fragments movement on agarose gel during gel electrophoresis ?

(a) The smaller the fragment size, the farther it moves (b) Positively charged fragments move to farther end (c) Negatively charged fragments do not move (d) The larger the fragment size, the farther it moves. (NEET 2017)

- (34) DNA fragments are (a) negatively charged (b) neutral (c) either positively or negatively charged depending on their size (d) positively charged. (NEET 2017)

- (35) A gene whose expression helps to identify transformed cell is known as

(a) vector (b) plasmid (c) structural gene (d) selectable marker.

(NEET 2017)

- (36) The DNA fragments separated on an agarose gel can be visualised after staining with

(a) acetocarmine (b) aniline blue (c) ethidium bromide (d) bromophenol blue.

(NEET 2017)

- (37) The process of separation and purification of expressed protein before marketing is called

(a) downstream processing (b) bioprocessing (c) postproduction processing (d) upstream processing.

(NEET 2017)

Assertion and Reason Type Questions

In each of the following questions two statements are given. One is assertion (A) and one is reason (R). Mark the correct answer as

(A) If both A and R are true and R is correct explanation of A.

(B) If both A and R are true but R is not the correct explanation of A.

(C) If A is true but R is false. (D) If both A and R are false

1. **Assertion :** HIV is called a retro virus.

Reason : HIV can synthesize new genomic RNA on the RNA template itself without requiring a DNA intermediate.

(A)

(B)

(C)

(D)

2. **Assertion :** Conjugation in bacteria is not considered sexual reproduction though there is transfer of genetic material in it.

Reason : In conjugation, meiosis, gamete formation and gametic fusion do not occur.

(A)

(B)

(C)

(D)

ANSWERS

Multiple Choice Questions

- (1) —a (2) —c (3) —c (4) —c (5) —b (6) —d (7) —d (8) —d (9) —b (10) —b
 (11) —b (12) —a (13) —a (14) —b (15) —b (16) —b (17) —d (18) —b (19) —b (20) —c
 (21) —b (22) —b (23) —a (24) —a (25) —d (26) —b (27) —a (28) —a (29) —d (30) —c
 (31) —d (32) —d (33) —a (34) —a (35) —d (36) —c (37) —a

Assertion and Reason Type Questions

- (1) —C (2) —A

Biotechnology mainly deals with industrial scale production of biopharmaceuticals and biologicals using genetically modified microbes, fungi, plants and animals. The applications of biotechnology include (i) therapeutics, (ii) diagnostics, (iii) genetically modified crops for agriculture, (iv) processed food, (v) bioremediation, (vi) waste treatment and (vii) energy production.

Research Areas of Biotechnology

Following are three research areas of biotechnology.

- (i) **Catalyst.** Providing the best catalyst in the form of improved organism; generally a microbe or pure enzyme.
- (ii) **Optimum Conditions.** Creating optimal conditions through engineering for a catalyst to act.
- (iii) **Downstream Processing.** Downstream processing technologies to purify the protein/organic compound.

We will learn in this Chapter, how biotechnology is being used to improve the quality of our life, mainly in the food production and health.

BIOTECHNOLOGICAL APPLICATIONS IN AGRICULTURE

Options To Increase the Food Production. There are three options to increase the food production.

1. **Agrochemical based Agriculture.** The Green Revolution succeeded in increasing the yield of crops mainly due to

- (i) use of improved varieties of crops and
- (ii) use of agrochemicals (fertilizers and pesticides)

But it was not sufficient to feed the growing human population.

2. **Organic Agriculture or Organic Farming.** In organic farming, farmers use manures, biofertilizers, biopesticides and biocontrols to increase the crop production instead of using artificial fertilizers and pesticides.

3. **Genetically Engineered Crop-based Agriculture.** The organic farming cannot increase the yield of crop to appreciable degree. The solution of this problem is use of genetically modified crops. Plants, bacteria, fungi and animals whose genes have been changed by manipulations are called **Genetically Modified Organisms (GMOs)**.

Crops in which foreign genes have been introduced through genetic engineering are called **genetically modified crops or GM Crops**.

Transgenic Plants

The plants in which foreign genes have been introduced through genetic engineering are called **transgenic plants**. There are two techniques for introducing foreign genes (transgenes) into the plant cell genome.

- (i) The first, through a vector and
- (ii) The second, through direct introduction of DNA.

The two techniques have been described in the previous chapter.

Production of Transgenic Plants (Fig. 12.1)

Here gene transfer through Ti plasmid vector is taken as an example : Interspecific gene transfer are now possible through genetic engineering. **Ti plasmid** (tumour inducing) from the soil bacterium *Agrobacterium tumefaciens* is effectively used as vector for gene transfer to plant cells. This is, so called because in nature, it induces tumors in broad leaf plants such as tomato, tobacco and soybean. For using Ti plasmid as a vector, researchers have eliminated its tumor causing properties while keeping its ability to transfer DNA into plant cells. This bacterium is called **natural genetic engineer** because genes carried by its plasmid produce effect in several parts of the plant. **Ri plasmid** of *A. rhizogenes* is also being used as vector.

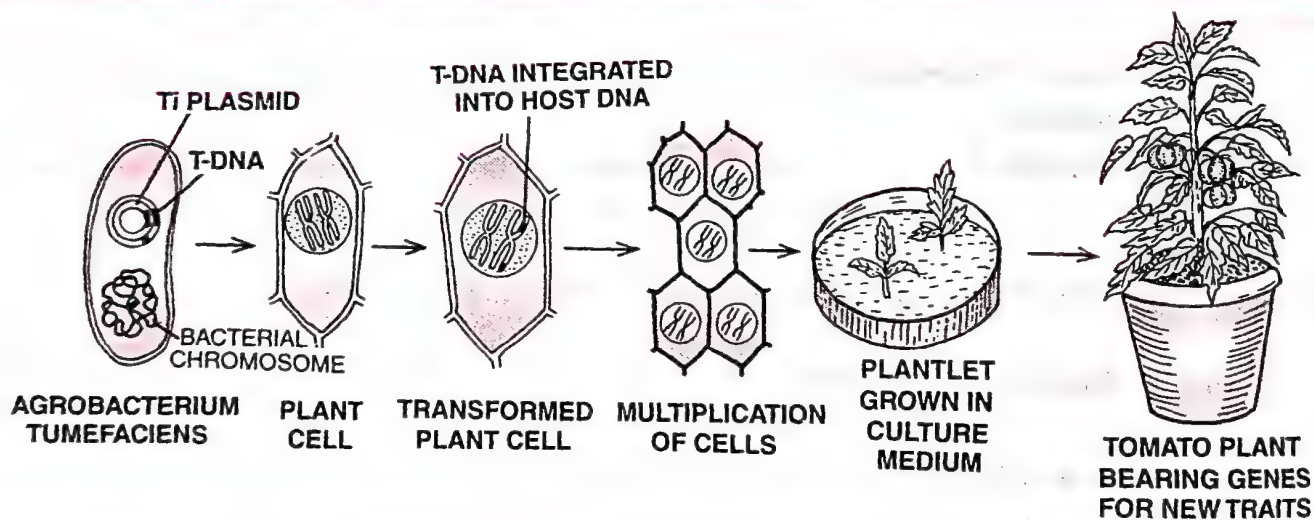


Fig. 12.1. *Agrobacterium* Ti plasmid-mediated genetic transformation in plants.

(i) This bacterium infects all broad-leaved agricultural crops such as tomato, soybean, sunflower and cotton etc. It does not infect cereals. It induces formation of cancerous growth called a **crown gall tumor**. This transformation of plant cells is due to the effect of Ti plasmid carried by the pathogenic bacterium. Hence, for genetic engineering purposes, *Agrobacterium* strains are developed in which tumor-forming genes are deleted. These transformed bacteria can still infect plant cells. (ii) The part of Ti plasmid transferred into plant cell DNA, is called the **T-DNA**. This T-DNA with desired DNA spliced into it, is inserted into the chromosomes of the host plant where it produces copies of itself, by migrating from one chromosomal position to another at random. But it no longer produces tumors. (iii) Such plant cells are then cultured, induced to multiply and differentiate to form plantlets. (iv) Transferred into soil, the plantlets grow into mature plants, carrying the foreign gene, expressed throughout the new plant.

Insect Resistance in Transgenic Plants

Bt Cotton. Soil bacterium *Bacillus thuringiensis* (Bt for short) produces proteins that kill certain insects like lepidopterans* (tobacco budworm, armyworm), coleopterans (beetles) and dipterans (flies, mosquitoes). *Bacillus thuringiensis* forms some protein crystals. These crystals contain a toxic **insecticidal protein**. Why does this toxin not kill the *Bacillus* (bacterium)? The Bt toxin proteins exist as inactive **protoxins** but once an insect ingests the inactive toxin it is converted into an active form of toxin due to the alkaline pH of the alimentary canal that solubilizes the crystals. The activated toxin binds to the surface of midgut epithelial cells and create pores which cause cell swelling and lysis and finally cause death of the insect.

Bt toxin genes were isolated from *Bacillus thuringiensis* and incorporated into several crop plants such as cotton. The choice of genes depends upon the crop and targeted pest, as most Bt toxins are insect-group specific. The toxin is coded by a gene named *cry*. There are number of genes. Two *cry* genes, *cry* IAc and *cry* II Ab have been incorporated in cotton. The genetically modified crop is called **Bt cotton** as it contains Bt toxin genes. The genes *cry* IAc and *cry* II Ab control cotton **bollworms**. Similarly, *cry* I Ab has been introduced in Bt corn to protect the same from **corn borer**.

Gene symbol usually has small letters and is invariably in italics, e.g., *cry*. The first letter of the **protein symbol**, on the other hand, is always capital and the symbol is always written in roman letters, e.g., Cry.

The Government has agreed to allow cultivation of genetically modified Bt Cotton.

Bt cotton farming has shown good results in Malwa region of Punjab. The government should encourage such farming. It will save water starved Malwa region from turning into desert as cotton which needs much less water, will replace paddy.

Pest Resistance in Transgenic Plants (Protection Against Nematodes)

Many **nematodes** (Round worms) live in plants and animals including human beings. A nematode *Meloidogyne incognita* infects the roots of tobacco plants and causes a great reduction in yield. A novel strategy was coined by Fire and Mello in 1998 to prevent this infestation that was based on the process of **RNA interference (RNAi)**. RNAi takes place in all eukaryotic organisms as a method of cellular defense. This method involves **silencing of a specific mRNA**.

Using *Agrobacterium* vectors, nematode specific genes are introduced into

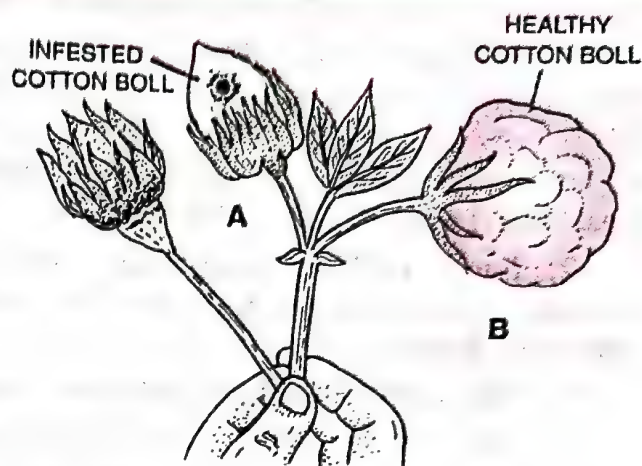


Fig. 12.2. Cotton boll. A, destroyed by bollworms and B, a fully mature cotton boll. (uninfected boll)

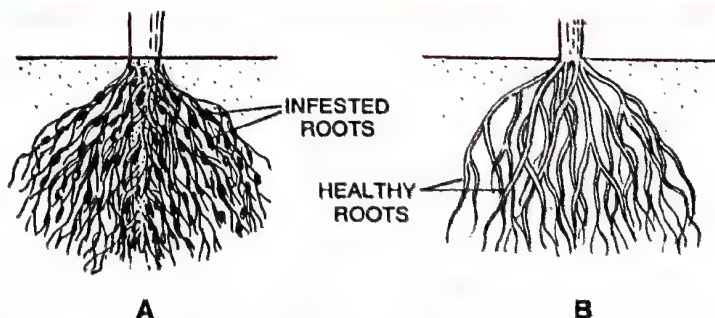


Fig. 12.3. Development of nematode resistance through RNAi. A, Roots of infested plant. B, Roots of a transgenic plant even after deliberate infection of nematode.

*Lepidoptera is an order of class Insecta. It includes butterflies and moths.

the host plant (tobacco plant). The introduction of DNA was such that it produced both **sense** and **anti-sense** RNA in the host cells. These two RNAs being complementary to each other formed a dsRNA (double stranded RNA) that initiated RNAi*.

Different steps involved in making tobacco plant resistant to nematode are briefly described below :

1. Double-stranded RNAs are processed into approximately 21-23 nucleotide RNAs with two nucleotides. An RNase enzyme called **Dicer** cuts the dsRNA molecules (from a virus, transposon, or through transformation) into small interfering RNAs (siRNAs).

2. Each siRNA complexes with ribonucleases (distinct from Dicer) to form an RNA-induced silencing complex (**RISC**).

3. The siRNA unwinds and RISC is activated.

4. The activated RISC targets complementary mRNA molecules. The siRNA strands act as guides where the RISCs cut the transcripts in an area where the siRNA binds to the mRNA. This destroys the mRNA.

5. When mRNA of the parasite is destroyed no protein was synthesized. It resulted the death of the parasite (nematode) in the transgenic host. Thus the transgenic plant got itself protected from the parasite.

'Flavr Savr' Transgenic Tomatoes

(Post-Harvest Losses/Delayed Fruit Ripening)

In 'Flavr Savr' transgenic tomato, expression of a native tomato gene has been blocked. This gene produces enzyme **polygalacturonase** which promotes softening of fruit. The production of this enzyme was reduced in the Flavr Savr transgenic tomato. The non-availability of this enzyme prevents over-ripening because the enzyme is essential for degradation of cell walls. Thus fruit remains fresh for a longer period than the fruit of normal tomato variety. It retains flavour, has superior taste and higher quantity of total soluble solids.

Golden Rice

Golden rice is a transgenic variety of rice (*Oryza sativa*) which contains good quantities of **β -carotene** (provitamin A – inactive state of vitamin A). β -carotene is a principal source of vitamin A. Since the grains (seeds) of the rice are yellow in colour due to β -carotene, the rice is commonly called **golden rice**.

β -carotene (provitamin A) is converted into vitamin A. Thus

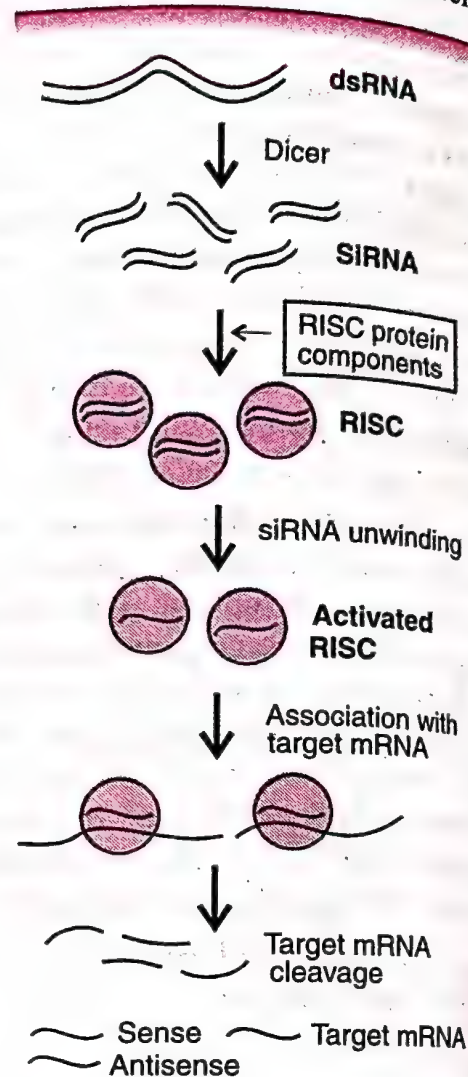


Fig. 12.4. The steps in RNA interference (RNAi).



Fig. 12.5. Showing seeds of golden rice.

*RNA interference (RNAi). Fire and Mello were awarded Nobel Prize (2006) for their discovery of RNA interference gene silencing by double-stranded RNA (dsRNA).

golden rice is rich in vitamin A. It is required by all individuals as it is present in retina of eyes. Deficiency of vitamin A causes night blindness and skin disorder.

Since the contents of vitamin A are very low in rice, vitamin A is synthesised from β -carotene which is precursor of vitamin A. Prof. Ingo Potrykus and Peter Beyer produced genetically engineered rice by introducing three genes associated with synthesis of carotene. The grains (seeds) of transgenic rice are rich in provitamin.

Transgenic Tobacco Plants

Tobacco plants containing a gene from a bacterium, *Bacillus thuringiensis* have been produced. This gene is an insecticidal protein which damages the inner lining of the stomach of the insect and kills it (insect). The tobacco plants having this gene produce their own insecticide.

Herbicide Resistant Transgenic Plants

Weeds such as Striga decrease crop yields and quality by competing with crop plants for light, water and nutrients. Weeds are to be removed with the help of herbicide (weed killer). For example, **Roundup Ready** transgenic plant has been produced and commercialised. It is tolerant to the herbicide **Roundup** (Trade Name). Herbicide tolerance has been developed in Maize, Cotton, Soya Bean, Tobacco, etc.

Molecular Farming

Production of proteins encoded by transgenes in animals/crops; the protein recovered from milk, urine, blood (in animals), seeds etc. (in plants) is called **molecular farming**. Plants are cheap and amazing chemical factories that need only water, minerals, sunlight and carbondioxide to produce thousands of sophisticated chemical molecules with different structures. Given the right genes, plants can serve as bioreactors to modified compounds like aminoacids, proteins, vitamins, pharmaceuticals, drugs, enzymes and so on.

Transgenic animals have been extensively used as models for biomedical research. An improvement in beneficial animals occurs through transgenesis. It has led to the following encouraging results, (i) increased milk production in cattle, (ii) increased growth rate of useful animals, (iii) large scale production of valuable proteins in milk, urine and blood of beneficial animals thus making use of transgenic animals as "**bioreactors** for molecular farming (iv) improvement of wool production through production of transgenic sheep.

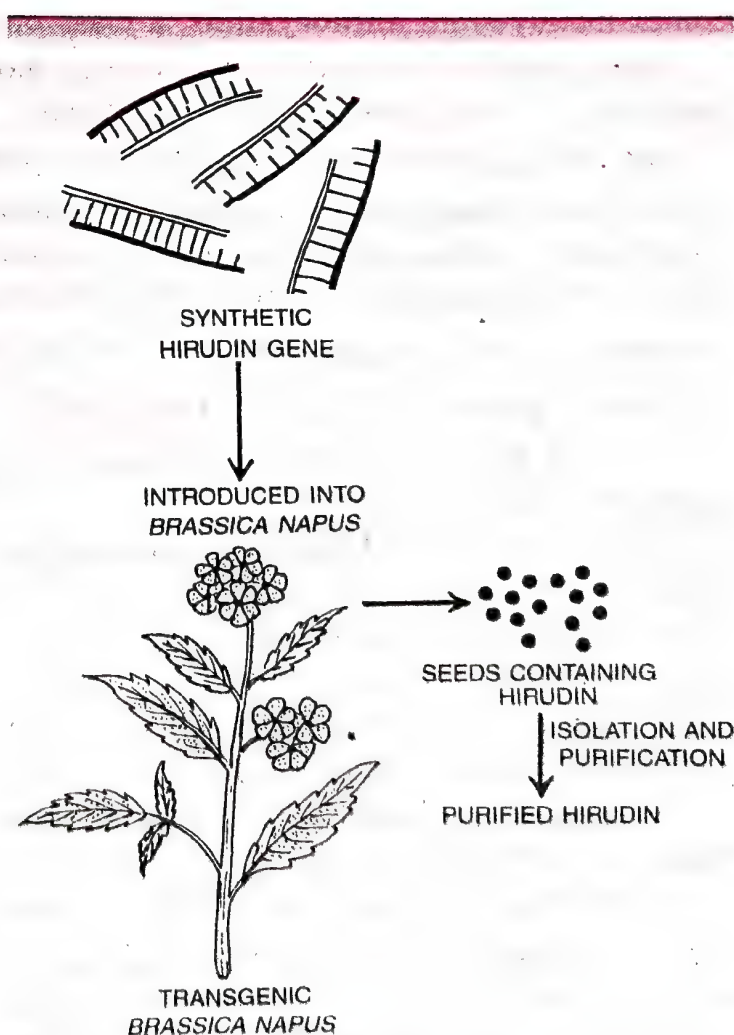


Fig. 12.6. A simplified representation of the production of hirudin from transgenic *Brassica napus* seeds.

***Brassica napus* — Production of Hirudin (Fig. 12.6)**

Hirudin is a protein that prevents blood clotting. Its gene was chemically synthesized and was transferred into *Brassica napus* where hirudin accumulates in seeds. The hirudin is extracted and purified and used as medicine.

Diagnostic and Therapeutic Proteins

Transgenic plants can produce a variety of proteins used in diagnostics for detecting and curing human and animal diseases in large scale with low cost. The monoclonal antibodies, peptide hormones, cytokinins and blood plasma proteins are being produced in transgenic plants and their parts such as tobacco (in leaves), potato (in tubers), sugarcane (in stems) and maize (in seed endosperm)

Disease Resistance

There are many viruses, fungi and bacteria that cause plant diseases. Plant biologists are working to create plants with genetically engineered resistance to these diseases.

Transgenic Plants for Floriculture

In 1990, the production of transgenic ornamental plants also gained momentum and transformation procedures became available for many ornamental plants, e.g., rose, tulip, lily, etc. Several of these cut flowers, many transgenics have novel aesthetic properties including new colours, longer life, etc. Some of these plants have commercial demand. Flower colour comes mainly from **anthocyanins**, a class of coloured flavonoids.

GM crops contain and express one or more useful foreign genes or transgenes. The technique of GM crops has two advantages.

- (i) Any gene from any organism or a synthetic gene can be incorporated.
- (ii) Change in genotype is precisely controlled. This technology is superior to breeding programmes because in breeding only the already present genes are reshuffled and that changes would occur in all traits for which the parents are different.

Advantages of Transgenic Plants (= GM Plants)

Due to genetic modification, GM plants have been useful in many ways :

1. **Pest Resistance Crops.** Growing GM crops can help to reduce the use of chemical pesticides, e.g., Bt Cotton.
2. **Tolerance.** GM crops are more tolerant to abiotic stresses (cold, drought, salt, heat, etc.)
3. **Reduction in Post-harvest Losses.** They have helped to reduce post harvest losses, e.g., Flavr Savr transgenic tomato.
4. **Prevention of Early Exhaustion of Fertility of Soil.** Increased efficiency of mineral usage by plants prevents early exhaustion of fertility of soil.
5. **Increasing Nutritional Value of Food.** GM plants enhance nutritional value of food, e.g., golden rice is rich in vitamin A.
6. **Herbicide Resistance.** Herbicides (weed killers) do not harm the GM crops.
7. **Alternative Resources to Industries.** GM plants have been used to create alternative resources to industries in the form of starches, fuels and pharmaceuticals. Researchers are working to develop edible vaccines, edible antibodies and edible interferons.
8. **Disease Resistance.** Many viruses, bacteria and fungi cause plant diseases. Scientists are working to create genetically engineered plants having resistance to these diseases.

9. **Phytoremediation.** Plants such as popular trees have been genetically engineered to clean up heavy metal pollution from contaminated soil.

Disadvantages of Transgenic Plants (GM Plants)

1. **Environmental hazards.** These are as follows :

(i) **Unintended harm to other organisms.** A laboratory study was published in 'Nature' showing that pollen from Bt corn caused high mortality rates in monarch butterfly caterpillars. Monarch caterpillars consume milkweed plants, not corn, but the fear is that if pollen from Bt corn is blown by the wind on to milkweed plants in neighbouring fields, the caterpillars could eat the pollen and perish. Although the 'Nature' study was not conducted under natural field conditions, the results seemed to support this viewpoint.

(ii) **Reduced effectiveness of pesticides.** Just as some populations of mosquitoes developed resistance to the now-banned pesticide DDT, many people are concerned that insects will become resistant to Bt or other crops that have been genetically modified to produce their own pesticides.

(iii) **Gene transfer to non-target species.** Another concern is that crop plants engineered for herbicide tolerance and weeds will cross-breed, resulting in the transfer of the herbicide resistance genes from the crops into the weeds. These "superweeds" would then be herbicide tolerant as well. Other introduced genes may cross over into non-modified crops planted next to GM crops.

2. **Human health risks.** GM food can lead the following health problems.

(i) **Allergies.** The transgenic food may cause toxicity and or produce allergies. The enzyme produced by the antibiotic resistance gene can cause allergies, because it is a foreign protein.

(ii) **Effect on Bacteria of Alimentary canal.** The bacteria present in the human alimentary canal can take up the antibiotic resistance gene that is present in the GM food. These bacteria can become resistant to the concerned antibiotic and will be difficult to manage.

3. **Economic concerns.** Bringing a GM food to market is a lengthy and costly process, and of course agro-biotech companies wish to ensure a profitable return on their investment.

Summary of useful Applications of Some Transgenic Plants

Transgenic Plants	Useful application
1. Bt Cotton	Pest resistance, herbicide tolerance and high yield. It is resistant to bollworm infestation.
2. Wheat	Resistant against the herbicide.
3. <i>Brassica napus</i>	A gene encoding hirudin (a protein that prevents blood clotting) is synthesized chemically and then transferred into <i>Brassica napus</i> . This gene is activated in the plant and starts synthesizing hirudin which accumulates in seeds. The hirudin is then extracted and purified to be used in medicine.
4. Tobacco	CPTI (Cow Pea Trypsin Inhibitor) gene has been introduced in tobacco to show resistance against pests.
5. Flavr Savr Tomato	Increased shelf-life (delayed ripening) and better nutrient quality.
6. Golden Rice	Vitamin A-rich
7. Potato	Higher protein content
8. Bananas	Transgenic bananas act as edible vaccines to protect children against diarrhoea
9. Soyabean, Maize	Herbicide resistance

Some other transgenic plants have been produced. These are sunflower, cauliflower, cabbage, banana, pea, lotus, cucumber, carrot, strawberry, papaya, grape, popular, apple, pear, neem, rye, etc.

- First transgenic plant was a tobacco plant which was created in 1983. It was resistant to an antibiotic.
- First transgenic cereal plants were maize and wheat which were produced in 1990-92.
- Flavr Savr tomato was the first transgenic variety to reach the market.

Transgenic Microbes — Genetically Engineered Microbes (GEMS)

Transgenic microbes are microorganisms into which a gene or genes have been introduced using recombinant DNA technology. They fulfil specific needs and perform functions, which their natural counterparts can never perform. Transgenic microbes are employed for a variety of functions.

1. **Living Factory for the Production of Proteins.** In bacteria, genetic engineering turns the bacterium into a living factory for the production of proteins. *Escherichia coli* (Gut Bacterium) is employed for the production of (a) **insulin** needed for the treatment of diabetes. (b) **human growth hormone (hGH)** needed for the treatment of pituitary dwarfism. (c) **erythropoietin** regulates the production of red blood cells. (d) **interleukins** promote the growth and differentiation of cells of the immune system. (e) **interferons** response to viral infections.

Engineered *E. coli* produce **bovine growth hormone (bGH)**. This hormone, when injected into cows, raises milk production as well as beef output. The engineered *E. coli* produce the enzyme cellulase, which hydrolyses cellulose and enables animals to utilize the entire feed.

2. **Environmental Protection.** Transgenic microbes help in cleaning polluted environment, e.g., *Pseudomonas putida* for cleaning oil spills, *Pseudomonas* species removing heavy metal pollutants, *Acetobacter aerogens* for decomposition of DDT and *Flavobacterium* for decomposition of 2, 4-D. Breakdown of pollutants by use of microorganisms is called **bioremediation**.

3. **Crop Protection.** *Pseudomonas fluorescence* protects the plants from frost damage. *Trichoderma* (fungus) produces chitinases for biocontrol of fungal diseases. *Bacillus thuringiensis* produces a highly potent safe and biodegradable insecticide for plant protection. *Rhizobium meliloti* can help cereal crops in nitrogen fixation.

4. **Production of Amino Acids and Fuels.** Genetic engineering also has an important impact on microbial production of amino acids and fuels. Examples : (i) genetically engineered strains of *Bacillus amyloliquefaciens* and *Lactobacillus casei* have been prepared for production of amino acids on a large scale. (ii) *E. coli* and *Klebsiella planticola* carrying genes from *Zymomonas mobilis* could utilize glucose and xylose to give maximum yield of ethanol.

5. **Paper Industry.** Paper industry employs *Trametes* and other microbes for removing lignin from wood pulp.

6. **Vaccines.** Vaccine for hepatitis B virus is being produced from transgenic yeast. Vaccines against Influenza Virus, Herpes Virus and Rabies Virus have also been developed by recombinant DNA technology (genetic engineering).

BIOTECHNOLOGICAL APPLICATIONS IN MEDICINE

The recombinant DNA technological processes have made great impact in the area of healthcare by mass production of safe and more effective therapeutic drugs. Further, the recombinant therapeutics do not induce unwanted immunological responses. Now about 30 recombinant therapeutics have been approved for human use all over the world. In India, 12 of these are presently being marketed.

Genetically Engineered Insulin

Role of Sharpy-Shafer, Banting, Best and Macleod. Sharpy-Shafer (1916) first expressed the opinion that diabetes is caused by failure of the islets of pancreas to secrete a substance named by him as **insulin**. Insulin is secreted by the **Beta cells** of the **islets of Langerhans** of the pancreas. In 1921, **Banting** and **Best** succeeded in preparing a pure extract of insulin from the pancreatic islets of a dog with the help of **Macleod**. Banting and Macleod won the 1923 Nobel Prize in Medicine or Physiology. They demonstrated that administration of insulin could cure diabetes in human beings. Earlier, insulin for curing diabetes used to be extracted from pancreas of slaughtered pigs and cattle. This insulin is slightly different from human insulin and brings about some undesirable side effects such as allergy.

Structure of Insulin. Human insulin is made up of 51 amino acids arranged in two polypeptide chains, **A** having 21 amino acids and **B** with 30 amino acids. The two polypeptide chains are interconnected by two disulphide bridges (Fig. 12.7) or S-S linkages. An S-S linkage also occurs in **A** chain. The hormone develops from a storage product called **pro-insulin**. Proinsulin has three chains, **A**, **B** and **C**. **C**-chain with 33 amino acids is removed prior to insulin formation. Bacteria can not be made to synthesise insulin from its gene because of the presence of introns. Bacteria do not possess enzymes for removing intron mediated transcription.

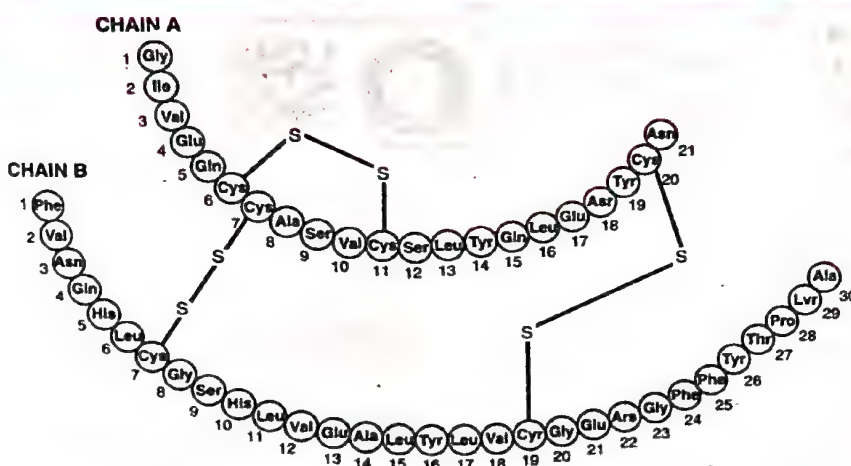


Fig. 12.7. Insulin is composed of two chains of 21 and 30 amino acids linked by disulphide bonds.
(Molecular Structure of insulin)

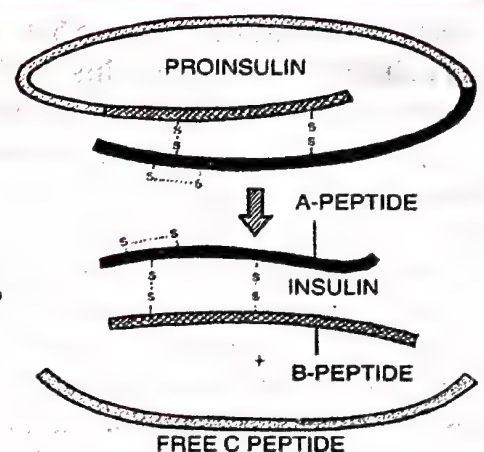


Fig. 12.8. Maturation of pro-insulin into insulin after removal of C-peptide (to be simplified).

How Insulin is Synthesized ? As stated earlier insulin is produced by the Beta cells of the islets of Langerhans of the pancreas. The gene for this protein synthesis is located on chromosome 11. In mammals, including humans, insulin is synthesized as a pro-hormone

(like a proenzyme, the prohormone also needs to be processed before it becomes a fully mature and functional hormone) which contains an extra stretch called the **C peptide**. This C peptide is not present in the mature insulin and is removed during maturation into insulin. The main challenge for production of insulin using rDNA technique was getting insulin assembled into a mature form. In 1983, **Eli Lilly** an American company, first prepared two DNA sequences corresponding to *A* and *B* chains of human insulin and introduced them in plasmids of *Escherichia coli* to produce insulin chains. Chains *A* and *B* were produced separately, extracted and combined by creating **disulfide bonds** to form human insulin (**humulin**).

Molecular structure of insulin was worked out by **Sanger**. **Tsan** synthesised human insulin for the first time.

Production of Human Insulin.

It involves essentially the following stages:

(i) **Isolation of Donor or DNA segment.** A useful DNA segment is isolated from the donor organism.

(ii) **Formation of Recombinant DNA (rDNA).** Both the vector and donor DNA segments are cut in the presence of restriction endonuclease. In the presence of **ligase** DNA segments of both are joined to form rDNA.

(iii) **Production of Multiple Copies of rDNA.** Next step in the process is production of multiple copies of this recombinant DNA.

(iv) **Introduction of rDNA in the recipient organism.** This rDNA is inserted into a recipient organism.

(v) **Screening of the transformed cells.** The recipient (host) cells are screened in the presence of rDNA and the product of donor gene. The transformed cells are separated and multiplied, an economical method for its mass production. The various steps and their sequence for the production of human insulin are depicted in Fig. 12.9.

Dr Saran Narang, a scientist of Indian origin, working in Ottawa, Canada was involved in cloning of insulin gene.

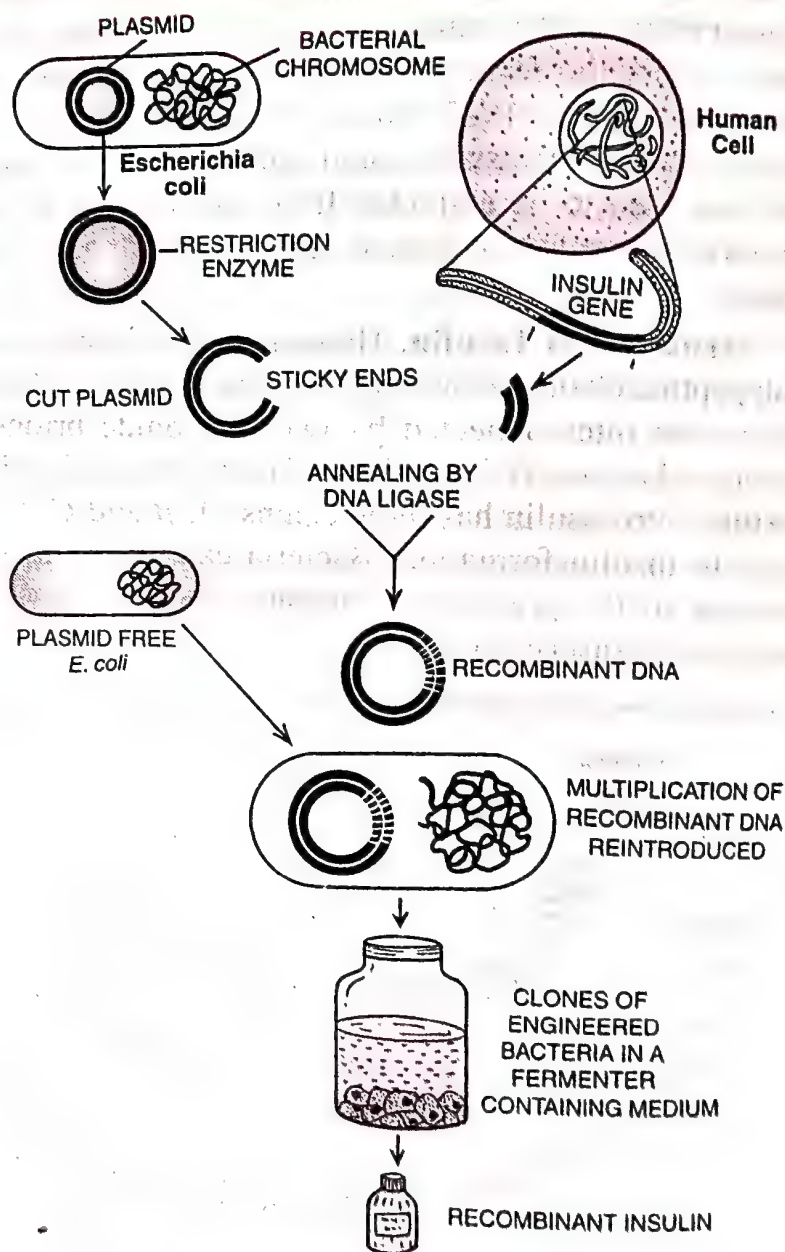


Fig. 12.9. Steps involved in production of human insulin.

- The most famous of the dogs Banting and Best used was one called "Marjorie".
- The first patient of diabetes to be administered insulin was 14-year old **Leonard Thompson**.

- Insulin can not be orally administered to diabetic patient because it degrades in the alimentary canal.
- Banting was born on November 14th, 1891 hence 14th November is observed as "Diabetic Day".
- In 1982 insulin (Eli Lilly's Humulin) was the first product made genetically engineered bacteria to be approved for use in Britain and the U.S.A.

Gene Therapy

What is Gene Therapy? Gene therapy is the technique of genetic engineering to replace 'a faulty gene' by a normal healthy functional gene.

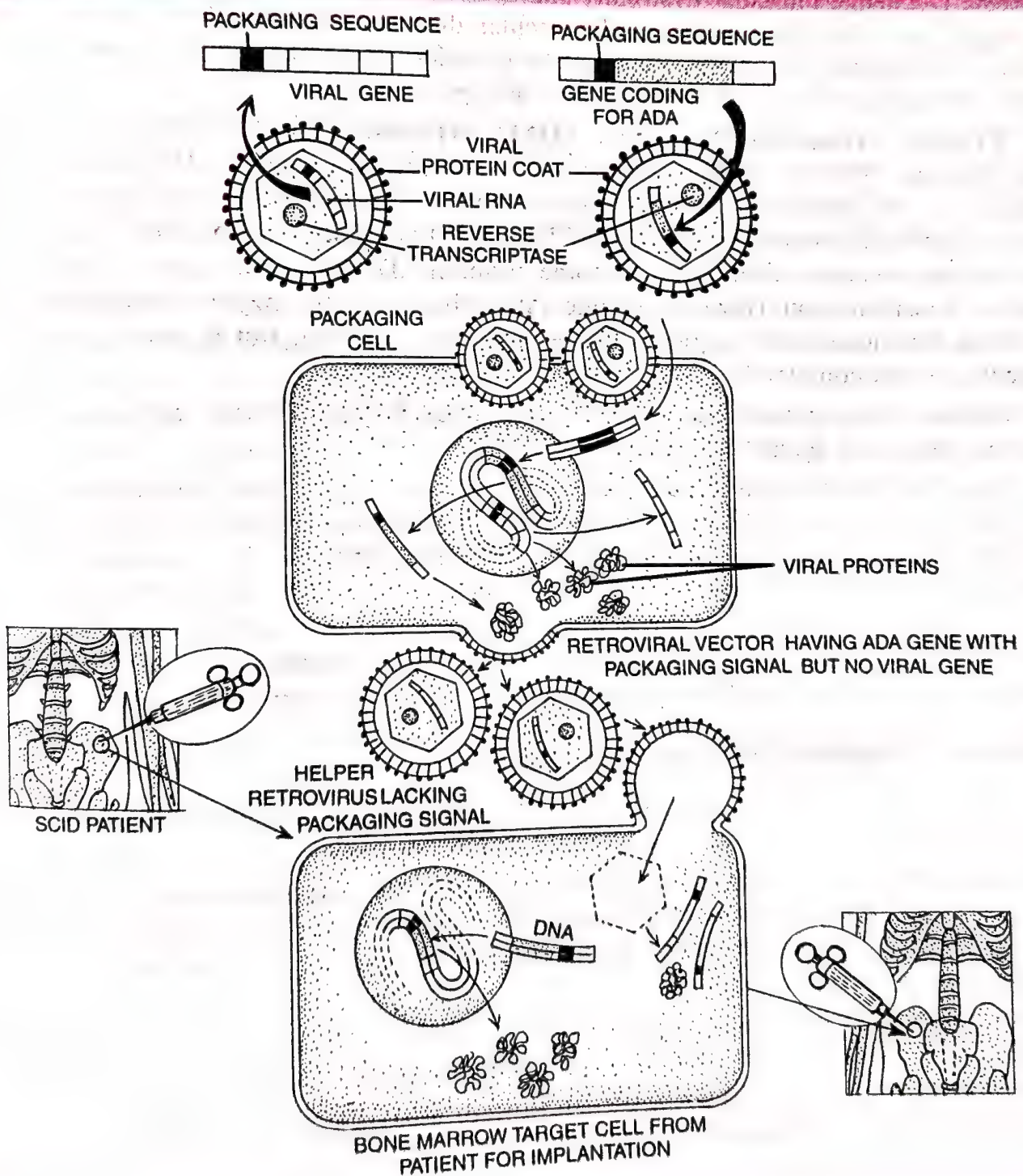


Fig. 12.10, Gene therapy to treat ADA-SCID.

Types of Gene Therapy. It is of two types :

- (i) **Germline Gene Therapy.** In this type of gene therapy germ cells, *i.e.*, sperms or eggs (even zygotes) are modified by the introduction of functional genes, which are ordinarily integrated into their genomes.
- (ii) **Somatic Cell Gene Therapy.** In this type of gene therapy, the gene is introduced only in somatic cells.

Only introduction of a new gene into the somatic cells is allowed at present. Genetic modification in the germ cells of the offspring is not permissible.

Diseases and Gene Therapy. The diseases for which scientists are making serious attempts to control through gene therapy are severe combined immunodeficiency (SCID) disease, Duchenne muscular dystrophy and cystic fibrosis. These disorders are mainly due to single gene defects. Cancer, cardiovascular diseases, diabetes, hypertension, arthritis, sickle cell anaemia, etc. are complex genetic disorders. However, the day is not far off when these diseases can be cured through gene therapy.

Example. Adenosine Deaminase (ADA) Deficiency. The first clinical gene therapy was given in 1990 to a 4-year old girl with adenosine deaminase (ADA) deficiency. This enzyme is very important for the immune system to function. ADA deficiency can lead to severe combined immune deficiency (SCID). SCID is caused due to defect in the gene for the enzyme adenosine deaminase. In some children ADA deficiency can be cured by bone marrow transplantation. However, in others it can be treated by enzyme replacement therapy, in which functional ADA is given to the patient by injection. But in both approaches the patients are not completely cured.

Because these patients do not have functional T-lymphocytes, they cannot provide immune responses against invading pathogens.

As a first step towards gene therapy (Fig. 12.10), lymphocytes, a kind of white blood cells, are extracted from the bone marrow of the patient and are grown in a culture outside the body. A functional ADA cDNA (using a retroviral vector) is then introduced into these lymphocytes, which are reinjected to the patient's bone marrow. But as these cells do not always remain alive, the patient requires periodic infusion of such genetically engineered lymphocytes. However, if the isolated gene from bone marrow cells producing ADA is introduced into cells at early embryonic stages, it can be a permanent cure.

Molecular Diagnosis (Diagnosis of Disease)

It is well known that an early diagnosis is very important for the effective treatment of the disease.

Using conventional methods of diagnosis (serum and urine analysis, etc.) early detection is not possible. **Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme Linked Immunosorbent Assay (ELISA)** are some of the techniques that serve the purpose of early diagnosis.

The **molecular probes** are usually single stranded pieces of DNAs (sometimes RNAs) labelled with radio isotopes such as ^{32}P . Molecular probes are available for many genetic disorders such as Duchenne muscular dystrophy cystic fibrosis, Tay-Sachs disease.

The analytical techniques used for the identification of a specific DNA, an RNA or a protein from thousands of each are collectively called **blotting** techniques. In **Southern blotting** extraction of DNA from the cells (say leucocytes) occurs. Latter on labelled DNA hybrid complexes are formed which can be identified on exposure to X-ray film. In **North-**

ern blotting RNA is identified by labelled DNA or RNA probe. In Western blotting, protein is identified with the help of labelled antibody probe. The radioactively labelled DNA probes are formed.

Presence of a pathogen (bacteria, viruses, etc.) is usually suspected only when the pathogen has produced a diseased symptom. By this time the number of pathogens is already very high in the body, but very low count of a bacteria or virus (when the symptoms of the disease are not yet visible) can be detected by multiplication of their nucleic acid by PCR. PCR can detect very low amounts of DNA. PCR is now usually used to detect HIV in suspected AIDS patients. It is also used to detect mutations in genes in suspected cancer patients. It is a good technique to identify many other genetic disorders.

A single stranded DNA or RNA joined with a radioactive molecule (probe) is allowed to hybridize to its complementary DNA in a clone of cells. It is followed by detection using autoradiography. The clone having the mutated gene will not appear on the photographic film, because the probe will not have the complementarity with the mutated gene.

ELISA is based on the principle of antigen-antibody interaction. It can detect very small amount of protein (antibody or antigen) with the help of enzyme (e.g., peroxidase or alkaline phosphatase). Infection by pathogen can be detected by the presence of antigens such as proteins, glycoproteins, etc. or by detecting the antibodies synthesised against the pathogen.

Making a Choice of Baby's Sex

Recently techniques have also been developed which will not require preferential abortion but will allow preferential fertilization by male (carrying Y chromosome) or female (carrying X chromosome) determining sperms. There are techniques available now, which allow separation of sperms carrying Y chromosomes, from the ejaculate of a man (through Ericson's method developed by R. Ericson of U.S.A) to be used for insemination of ovulating women. This technique (using quinacrine stain) has been used with 80% success in 47 sperm centres in the world including one in Mumbai. Ericson has actually established a company named Gametrics Ltd, in California, U.S.A. which specializes in separating sperms with Y chromosome and hundreds of male children have been produced with its help.

Techniques have also been developed to separate sperms carrying X chromosome for artificial insemination leading to the birth of female children. This technique involves 'sephadex gel column' in which sperms with Y, being lighter are trapped in gel and those with X being heavier reach the bottom of the column, and can be used for insemination.

Production of Vitamins

1. **Vitamin B₂ (Riboflavin).** Riboflavin is produced commercially by direct fermentation utilizing the fungus *Ashbya gossypii*. Fermentation conditions -pH 6.0 to 7.5, 4 to 5 days at 28-30°C, aerobic.

2. **Vitamin B₁₂ (Cobalamine).** Now a days vitamin B₁₂ is produced by a direct fermentation utilizing bacteria such as *Propionibacterium shermanii*, *P. freudenreichii* and *Pseudomonas denitrificans*. Fermentation conditions -pH 6 to 7.7, 2 days at 26-28°C, aerobic.

3. **Vitamin C (Ascorbic Acid).** Vitamin C was first recognized when in 1747, Scottish naval surgeon James Lind discovered that something in Citrus foods prevented scurvy. In 1928 Albert Szent-Gyorgyi, a much admired biochemist, was the first to isolate vitamin C (ascorbic acid). He later won the 1937 Nobel Prize in Physiology and Medicine for other work. Vitamin C was the first vitamin to be synthesized artificially in a process invented by Dr. Tadeusz Reichstein, of the Swiss Institute of Technology in Zurich in 1939. Vitamin C

is produced by utilizing *Gluconobacter oxydans*. Fermentation conditions -pH 7, 45 hours at 30°C, aerobic.

4. **Vitamin A (β -Carotene).** β -carotene is produced by members of choanephoraceae family of phycomycetes. *Phycomyces blakesleeanus*, *Choanephora cucurbitarum* and *Blakeslea trispora* have been extensively studied for their ability to produce β -carotene.

TRANSGENIC ANIMALS

The animals which carry foreign genes are called **transgenic animals**.

Production of Transgenic Animals. The foreign genes are inserted into the genome of the animal using recombinant DNA technology. The production of transgenic animals includes (i) Location, identification and separation of desired gene. (ii) Selection of proper vector (generally a virus) or direct transmission. (iii) Combining the desired gene with the vector. (iv) Introduction of transferred vector in cells, tissues, embryo or mature individual. (v) Demonstration of integration and expression of foreign gene in transgenic tissue or animal.

Advantages of Transgenic Animals

(i) **Biological Products.** Medicines required to treat certain human diseases can contain biological products, but such products are often expensive to make. Transgenic animals that produce useful biological products can be created by the introduction of the portion of DNA (or genes) which codes for a particular product such as human protein (α -1-antitrypsin) used to treat **emphysema**, tissue plasminogen activator (goat), blood clotting factors VIII and IX (sheep) and lactoferrin (cow). Attempts are being made for treatment of **phenylketonuria (PKU)** and **cystic fibrosis**. In 1997, the first transgenic cow, **Rosie**, produced human protein-enriched milk (2.4 gms per litre). The milk contained the human **alpha-lactalbumin**. It is a more balanced product for human babies than natural cow-milk.

(ii) **Vaccine Safety Testing.** Transgenic mice are being formed for use in testing the safety of vaccines before they are used on human beings. Transgenic mice are being used to test the safety of the polio vaccine.

(iii) **Chemical Safety Testing.** It is called as toxicity/safety testing. Transgenic animals are developed that carry genes exposed to the toxic substance and their effects are studied.

(iv) **Normal Physiology and Development.** Transgenic animals are specifically developed to study how genes are regulated, and how they affect the normal functions of the body and its development, e.g., study of complex factors involved in growth such as insulin-like growth factor.

(v) **Study of Diseases.** Many transgenic animals are developed to increase our understanding of how genes contribute to the development of disease so that investigation of new treatments for diseases is made possible. Now transgenic models exist for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis, Alzheimer's disease, haemophilia, thalassaemia, etc.

(vi) **Growing of Spare Parts.** Spare parts (e.g., heart, pancreas) of pig for human use can be grown through the formation of transgenic animals.

(vii) **Replacement of Defective Parts.** Replacement of defective parts with freshly grown part from own cells can be done.

(viii) **Production of Clones.** Clones of some animals can be produced. Even human clones may be formed if ethics allow the same.

Examples of Transgenic Animals.

Some important examples of transgenic animals are as follows :

1. Transgenic Fish

Gene transfers have been successful in various fish, such as common carp, rainbow trout, Atlantic salmon, catfish, goldfish, zebra-fish, etc.

Transgenic Salmon (Fig. 12.11). Genetically modified salmon was the *first transgenic animal for food production*. The genetically modified sperms were fused with normal ova (eggs) of the same species. The zygotes which developed into embryos gave rise to much bigger adults than either parent. The transgenic salmon possesses an additional gene that codes for the growth hormone that allows the fish to grow larger more rapidly than the non-transgenic salmon.

2. Transgenic Chicken

Avian leukosis virus (ALV) is a serious viral pathogen of chickens. D.W. Salter and L.B. Crittenden (1988) have produced an ALV-resistant strain of the chicken by introducing a defective genome of this virus into the genome of the chicken. This principle is also applied to evolve transgenic fish that can resist viral infections.

3. Transgenic Mice

Mouse is the *most preferred mammal for studies on gene transfers* due to its many favourable features like short oestrous cycle and gestation period, relatively short generation time, production of several offspring per pregnancy (*i.e.*, litter), convenient *in vitro* fertilization, successful culture of embryos *in vitro*, etc. As a result, the techniques for gene transfer and transgenic production have been developed using mice as models in other animals. Recently, rats and rabbits are being used for research work on gene transfer (Fig. 12.12).

4. Transgenic Rabbits

Rabbits are quite promising for *gene farming* or *molecular farming*, which aims at the production of recoverable quantities of pharmaceutically or biologically important proteins encoded by the transgenes. The following human genes encoding valuable proteins

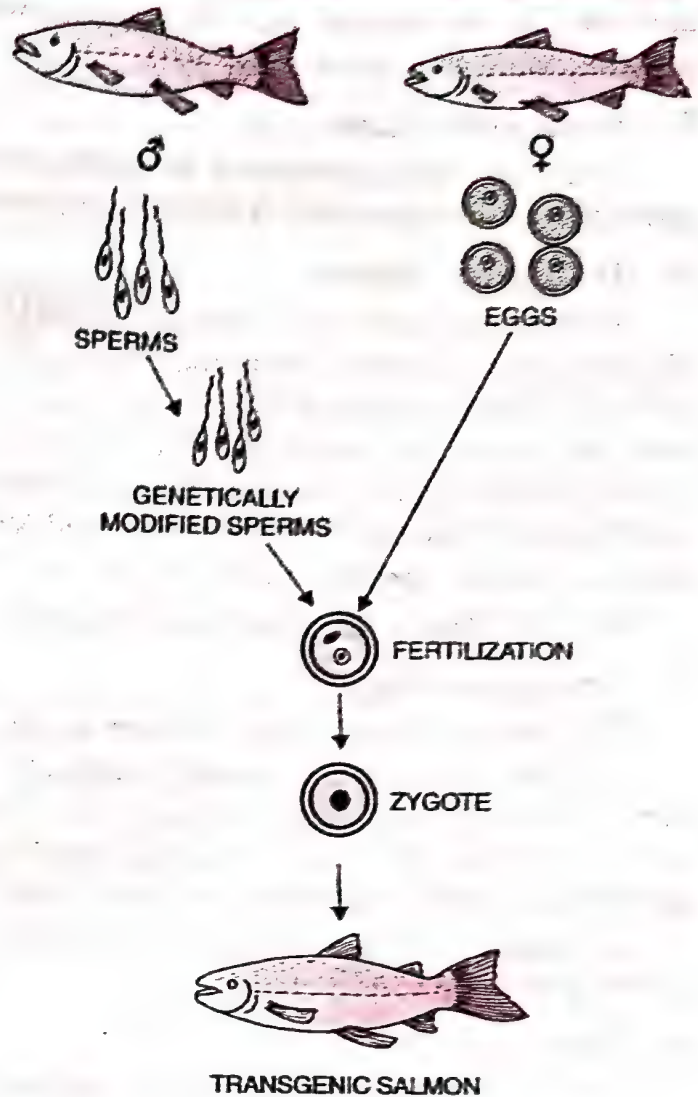


Fig. 12.11. Genetically Modified Salmon.



Fig. 12.12. Transgenic mouse (larger). It is larger because of expression of the gene for human growth factor that has been introduced into it.

have been transferred into rabbits : interleukin 2, growth hormone, tissue plasminogen activator, α_1 antitrypsin, etc. These genes were expressed in the mammary tissues and their proteins were harvested from milk.

5. Transgenic Goats

Goats are being evaluated as bioreactors. Some human genes have been introduced in goats and their expression achieved in mammary tissues. The initial results are encouraging.

6. Transgenic Sheep

Transgenic sheep have been produced to achieve better growth and meat production. For example, human genes for blood clotting factor IX and for α_1 -antitrypsin have been transferred in sheep and expressed in mammary tissue. This was achieved by fusing the genes with the mammary tissue-specific promoter of the **bovine β -lactoglobulin gene**. Human growth hormone gene has also been introduced in sheep in order to promote growth and meat production. However, they also showed several undesirable effects like joint pathology, skeletal defects, gastric ulcers, infertility, etc.

In 1990 Tracy, the transgenic ewe was born in Scotland.

7. Transgenic Pigs

The rate of transgenic production in pigs, sheep, cattle and goats is much lower (usually < 1%) than that in mice (usually between 3-6%). The objectives in transgenic swine (pl. same, meaning pig), production are (i) increased growth and meat production and (ii) to serve as bioreactors. Transgenic pigs expressing human growth hormone do show improved growth and meat production, but they also show several health problems.

In January 2002, an Edinburgh based therapeutics company announced the birth of a litter of transgenic pig clones.

8. Transgenic Cows

The only successful transfection technique in cows is microinjection of fertilized ova, which may either be recovered surgically or may be obtained from ovaries extracted from slaughtered cows and cultured *in vitro*. The two chief objectives of transgenic production are as follows : (i) increased milk or meat production and (ii) molecular farming. Several human genes have been successfully transferred in cows and expressed the mammary tissue; the protein is secreted in milk from where it is easily harvested. The name of first transgenic cow is **Rosie**.

9. Transgenic Dogs

Dogie is a transgenic dog with excellent smelling power. It was used during attack on World Trade Centre (WTC) of the USA in 2001 to recover injured people from heaps of devastated building.

10. ANDI

DNA of a fluorescent jelly fish was introduced into an unfertilized egg of a Rhesus monkey in the test tube. The diploid egg underwent cleavage and the early embryo was implanted in a surrogate mother. ANDI, the first transgenic monkey was born on Oct 2, 2000. It has been named ANDI, the acronym of "inserted DNA".

The credit for production of ANDI goes to **Dr. Gerald Schatten** of Oregon Health Sciences University, USA.

This work would be helpful for curing diseases such as breast cancer, Alzheimer's disease, diabetes and AIDS.

- Recently rats and rabbits are being used for research work on genetic transfer.
- The first transgenic farm animals were rabbits, pigs and sheep which were produced in 1985.
- The first transgenic animal was mouse which was produced in 1981/82.
- In plants gene transfer is often described by the term "transformation". However in animals this term has been replaced by the term "transfection".

APPLICATIONS OF GENETIC ENGINEERING

1. **Molecular Analysis of Diseases.** DNA research has helped in understanding the molecular basis of diseases like sickle cell anaemia, thalassemias, etc.
2. **Production of Proteins in Abundance.** Using recombinant DNA technique several proteins have been produced in abundance for curing the diseases. These are insulin, growth hormone, interferons, vaccines, erythropoietin and blood clotting factors.
3. **Laboratory Diagnostic Application.** rDNA technology makes the diagnosis of many diseases (e.g., AIDS) simple and quick.
4. **Gene Therapy.** The genetic diseases like sickle cell anaemia can be cured through gene therapy.
5. **Prenatal Diagnosis of Diseases.** DNA collected from the amniotic fluid surrounding the foetus can be used for predicting the genetic diseases.
6. **Application to Forensic Medicine.** rDNA technology has greatly helped to identify criminals by DNA fingerprinting and settle the disputes of parenthood of children.
7. **Agricultural Application.** rDNA technology is used for developing transgenic plants which resist drought and diseases and increase their productivity. It improves quality of food.
8. **Industrial Application.** Enzymes synthesized by rDNA technology are used to produce sugars, cheese and detergents.
9. **Application to Animals.** It is used for developing test tube babies to overcome infertility and production of transgenic animals.
10. **Evolution.** rDNA technique is of great use in joining several missing links in the evolution. This is done by amplifying the DNA of extinct animals.

ETHICAL ISSUES

Ethics includes rules of conduct by which a community regulates its behaviour and decides as to which activity is lawful and which is not. Therefore, **bioethics** includes rules of conduct that may be used to regulate our activities in relation to the biological world. **The main bioethical concerns pertaining to biotechnology are briefly mentioned as follows :** (i) Introduction of a transgene from one species into another species violates the 'integrity of species'. (ii) Biotechnology may pose unforeseen risks to the environment, including risk to biodiversity. (iii) Transfer of human genes into animals (and *vice-versa*) dilutes the concept of 'humanness'. (iv) When animals are used for production of pharmaceutical proteins, they are virtually reduced to the status of a 'factory'. (v) Use of animals in biotechnology causes great suffering to them. (vi) Biotechnology is disrespectful to living beings, and only exploits them for the benefit of human beings.

Therefore, the Indian Government has set up organisations such as GEAC (Genetic Engineering Approval Committee), which will make decisions regarding the

validity of GM research and the safety of introducing GM-organisms for public services.

1. Certain companies are being granted patents for products and technologies that make use of the genetic materials, plants and other biological resources that have long been identified, developed and used by farmers and common persons of a particular region/country. There are numerous varieties of rice in India alone. The diversity of rice in India is one of the richest in the world. Basmati rice is distinct for its unique aroma and flavour and 27 documented varieties of Basmati are grown in India. There is reference to Basmati in ancient books, as it has been grown for centuries. In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati, in the US and abroad. This 'new' variety of Basmati had actually been derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty. The patent extends to functional equivalents, implying that other people selling Basmati rice could be restricted by the patent.

2. Several attempts have also been made to patent uses, products and processes based on Indian traditional herbal medicines, *e.g.*, turmeric neem. If we are not vigilant other countries/individuals may encash on our rich legacy.

Mostly the developed nations are rich financially but poor in biodiversity and traditional knowledge. In contrast the developing and the underdeveloped world is rich in biodiversity and traditional knowledge related to bio-resources. Traditional knowledge related to bio-resources can be exploited to develop modern applications.

Some nations are developing laws to prevent such unauthorised exploitation of their bio-resources and traditional knowledge.

3. The GM crops are fast becoming a part of agriculture throughout the world because of their contribution to the increased crop productivity and to global food, feed and fiber security, besides their use in health-care and industry.

4. The effect of GM crops on non-target and beneficial insects/microbes.

5. Transgenes may escape through pollen to related plant species (gene pollution) and may lead to the development of super weeds.

6. The GM crops may change the fundamental vegetable nature of plants as the genes from animals (*e.g.*, fish or mouse) are being introduced into crop plants.

7. The safety of GM food for human and animal consumption, (*e.g.*, GM food may cause allergenicity).

8. The effect of GM crops on biodiversity and environment.

9. The transgenes may move from plants to gut microflora of humans and animals and cause antibiotic resistance.

10. The GM crops may lead to the change in the evolutionary pattern.

11. Scientists cannot rule out the possibility of mutation or other biological damage.

12. The release of genetically engineered plants and animals in the environment could disturb the existing ecological balance.

13. The use of recombinant microorganisms for various commercial purposes can accidentally create new infectious agents.

14. The main fear associated with the genetically engineered microorganisms is that they

could escape from the laboratory into the environment with unpredictable fatal consequences. AIDS virus is supposed to be the outcome of such a research.

BIOPATENT

A patent is the right granted by a government to an inventor to prevent others from commercial use of his invention. When patents are granted for biological entities and for products derived from them, these patents are called **biopatents**. Primarily, industrialised countries, like U.S.A., Japan and members of European Union, are awarding Biopatents. **Biopatents are awarded for** (i) strains of microorganisms, (ii) cell lines, (iii) genetically modified strains of plants and animals, (iv) DNA sequences, (v) the proteins encoded by DNA sequences, (vi) various biotechnological procedures, (vii) production processes, (viii) products and (ix) product applications. There is an opposition from social groups to biopatents. These objections are mainly ethical and political. Some biopatents are very broad in their coverage. For example, one patent covers "all transgenic plants of *Brassica* family".

Cancelled patents on natural product inventions. Patents on natural product inventions are subject to attack unless all public knowledge about the species in question and its use are fully disclosed. For example, a 1995 patent, "Use of Turmeric in Wound Healing", was cancelled in 1998. The new evidence established that use of turmeric to promote wound healing had been known for generations in India.

Likewise, the 1986 plant claimed an ostensibly new, distinct variety of *Banisteriopsis caapi*, known in the Amazon as *ayahuasca*. However, new evidence establishes that the claimed plant is actually the wild uncultivated type, and is neither new nor distinctive. COICA, an organization of indigenous people, and the Amazon Coalition have requested re-examination of the ayahuasca patent, seeking to eliminate what is perceived as an immoral expropriation of their traditional and biological heritage. More such challenges can be anticipated.

Significance of Biopatents. Biopatent system allows private, monopoly rights over cells, genes, animals and plants. It means that people will not share vital research information because they are afraid that it will be patented by someone else. The people will not research in areas that are dominated by patents. It will lead to research programmes dominated by patentability and profitability rather than need. It gives the patent holder monopoly control over resources for food and medicine. The important advantages of biopatents is that they are a direct incentive for genetic engineering. The arguments in favour of biopatents are primarily to increase economic growth.

Genes, cells, microorganisms, plants and animals are not an invention and, therefore, should not be patented.

BIOPIRACY

Some organisations and multinational companies exploit and/or patent biological resources or bioresources of other nations without proper authorisation from the countries concerned, this is called **biopiracy**.

Historical Aspects. Some examples of famous collecting trips are given below :

- (a) The recorded history of international plant collecting missions goes back at least 3500 years when Egyptian rulers began bringing plants home after military expeditions.
- (b) In the last century, the British Empire instituted regular plant collections. During the Voyage of the Beagle, Charles Darwin simply took what interested him, from the Galapagos and elsewhere, and brought it home.

(c) The Royal Botanical Gardens took rubber trees from Brazil, and planted them in South East Asia. They took cinchona seeds from Bolivia, in violation of national law, and planted them in India.

(d) Commodore Perry's naval mission to Japan collected a wide variety of plants to bring back to the United States.

(e) More recently, the adventures of Richard Shultes during the mid-twentieth century have become a legend among ethnobotanists. He was able to befriend local shamans, who allowed him to collect thousands of voucher specimens of medicinal plants, hundreds of which had never previously been identified taxonomically.

None of these famous collecting trips was challenged on legal grounds. If done today, how would they be challenged ?

Exploitation of Bioresources. Institutions and companies of industrialised nations are collecting and exploiting the bioresources, as follows: (i) They are collecting and patenting the genetic resources themselves. For example, a patent granted in U.S.A. covers the entire 'basmati' rice germplasm indigenous to our country. (ii) The bioresources are being analysed for identification of valuable biomolecules. A **biomolecule** is a compound produced by a living organism. The biomolecules are then patented and used for commercial activities. (iii) Useful genes are isolated from the bioresources and patented. These genes are then used to generate commercial products. (iv) The traditional knowledge related to bioresources is utilised to achieve the above objectives. In some cases, the traditional knowledge itself may be the subject of a patent.

Brazzein. Brazzein is a protein produced by a West African plant, *Pentadiplandra brazzeana* which is approximately 2,000 times as sweet as sugar. It is used as a low calorie sweetener. Local people have been using the super-sweet berries of this plant for centuries. But the protein brazzein was patented in U.S.A. The gene encoding brazzein was also isolated sequenced and patented in U.S.A. It is proposed to transfer the brazzein gene into maize and express it in maize Kernels. These Kernels will then be used for the extraction of brazzein. This development could have serious implications for countries exporting large quantities of sugar.

Examples of Biopiracy. The Thai Ministry of Science and its Biotech Institute has accused the British University of Portsmouth of "biopiracy" as they have refused to return up to **200 strains of marine fungi** that they collected in coastal waters and swamps around Thailand. Instead, Portsmouth University is reported to be in the process of selling the rights on "their" Thai fungi to a drug company for screening, as the fungi are believed to contain compounds for treating everything from AIDS to cancer—worth millions of pounds. Thailand insists that keeping the fungi without permission is in breach of international agreements.

India is a country rich in tradition, communal knowledge and expertise in natural medicines, spices, food preparations, biological pesticides and diverse agriculture. It is thus under siege from biopirates. Through patenting without consent, foreign companies have collared at least 22 plants for their beneficial derivatives. Patents have been taken out on plants such as **black pepper** (*Piper nigrum*), **basmati rice** (*Oryza sativa*), **Indian mustard** (*Brassica campestris*), **pomegranate** (*Punica granataum*), **turmeric** and **neem**. US, Japanese and German companies are the principal patenting pirates.

Nestle India has lined up a processing patent on **cooked cereals**, vegetable pulao and parboiled rice, at the Indian Patent Office, even though Indians have been making parboiled rice, often as a staple diet for centuries.

BIOWAR

War which is fought by **bioweapons** (biological weapons) against humans, their crops and animals is called **biowar** (biological war). Viruses, bacteria, fungi, spores and toxins can be used as bioweapons (BW).

Bioweapons used during the 20th century are (i) 1942 Britain developed strategic amounts of anthrax. (ii) 1940s Nazi prisoners infected with *Rickettsia* spp. hepatitis A, *plasmodia* spp. and treated with investigational vaccines and drugs. (iii) 1940s Nazi secret agent Reinhardt Heydrich assassinated with botulinum toxin. (iv) Germany used *Bacillus anthracis* (anthrax) to infect livestock and animal feed exported to Allies. (v) 1932-1945 Japan conducted research on *B. anthracis*, *Shigella* spp. *V. cholera* and *Y. pestis*.

US Bioweapons Program can be mentioned as follows (i) In 1942 approximately 5000 bombs filled with *B. anthracis* produced. (ii) In 1950s program expanded during Korean war. (iii) In 1955 human experiments with *F. tularensis* and *C. burnetti*. (iv) In 1949-1968 simulant organism released off coast of San Francisco and in New York City subway. (v) In 1969 US terminated offensive bioweapons program. (vi) In 1972 Bioweapons Convention and Treaty.

Diseases caused by bioweapon agents are (i) Anthrax (ii) Small pox (iii) Plague (iv) Q-fever (fever, chills fatigue, etc.) (v) Tularemia (it can occur in humans in two forms : ulceroglandular and typhoidal). (vi) Viral Encephalitis. (vii) Viral haemorrhagic fevers. (viii) Botulinum toxin (skeletal muscle paralysis).

Why are bioweapons used ? (i) Bioweapons are low cost weapons. (ii) They cause far more casualties than chemical or conventional weapons. Once bioweapon agents are released they are invisible, odourless and tasteless.

Protection against bioweapons. (i) Use of respirator or gas mask. (ii) Protective shelter. (iii) Decontamination. (iv) Vaccination. (v) Antibiotics.

ADDITIONAL INFORMATION

- **Alloplasmic.** A line having nucleus from one species and cytoplasm from a different species; often male sterile (male sterile due to cytoplasm).
- **Artificial Seed.** Gel bead containing SE or shoot bud; necessary nutrients, pesticides, antibiotics, growth regulators etc. also added to gel; SE/shoot bud gives rise to a healthy seedling.
- **Broth.** After fermentation; the medium containing both products and micro-organism biomass.
- **Cryotherapy.** For virus elimination from plants ; prolonged (4 months or long) exposure to a low temperature (5°C) followed by shoot tip culture; preferable to thermotherapy since it is less injurious and more effective.
- **Epitope.** The part of antigen molecule involved in antigen antibody interaction.
- **Gynogenesis.** The process of haploid plant production from cultured ovaries; generally unfertilized egg cells divide to produce haploids; sometimes synergids/antipodals are involved.
- **Silage** is green cattle food stored in a silo. Silo is air tight structure in which green food (silage) is stored for farm animals.
- **Immuno-PCR.** Amplifies a DNA segment (by PCR) attached to an antibody; the antibody is specific to the antigen to be detected, e.g., antigen specific to a pathogen, a cancer cell etc; detects rare antigen at a single cell level or a single antigen molecule/sample.
- **Metabolic Engineering.** In industrial microbiology; introduction of transgenes affecting enzymatic, transport and regulatory functions; this modifies metabolic activities to yield a modified product, a new prod-

uct, a better utilization of substrate, an increased productivity or growth etc.

- **Whey.** The liquid part of coagulum, waste from cheese production process.

- **Vector chimaeric.** A vector containing a DNA insert.

- **Psychrophile** is an organism that grows at low temperature in the range of 0–25°C and that has an optimum growth temperature in the 20–25°C.

- **Sludge** is precipitated solid matter produced by water and sewage treatment or industrial problems may be amenable to biological control.

- The first commercially available human vaccine is hepatitis B vaccine which is produced from transgenic yeasts by recombinant DNA technology.

- Reagent used in ELISA test is Peroxidase.
- Walksman was well known soil microbiologist.

- *Azotobacter* and *Beyerinckia* are two free living nitrogen fixing bacteria.

- Vandana Shiva helped to get patent for insecticidal properties of neem.

- **Gene splicing.** Cutting and rejoining the DNA sequence for r-DNA technology.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. Crystals of Bt toxin produced by some bacteria do not kill the bacteria themselves because (a) bacteria are resistant to the toxin (b) toxin is immature (c) toxin is inactive (d) bacteria encloses toxin in a special sac

✓ (c)

2. What are transgenic bacteria ? Illustrate using any one example.

✓ When a foreign gene or series of genes are intentionally introduced into the genome of a bacterium, the later becomes transgeneic. For example, two DNA sequences (A and B chains of human insulin) were introduced into the plasmid of bacteria *E. coli*. The transgenic bacteria start producing insulin chains.

3. Compare and contrast the advantages and disadvantages of production of genetically modified crops.

✓ **Advantages.** Transgenic plants increase productivity of crops generally by showing resistance against plant pathogens and to some herbicides. They develop crop varieties with added vitamins and minerals. Thus, the GM crops have enhanced nutritional quality and yield. Transgenic crops grow well in saline soil and show salt tolerance.

Disadvantages. Transgenes in commercial crops can endanger native species. For example, the gene for Bt toxin expressed in pollen might endanger pollinators like honeybees. These crops cause problems in human health by supplying allergens and transfer of antibiotic resistance markers. They cause damage to the natural environment.

4. What are Cry proteins ? Name an organism that produces it. How has man exploited this protein to his benefit ?

✓ Cry proteins are encoded by the genes named *cry*. They are produced in *Bacillus thuringiensis*. Cry proteins are toxic to insects and act as insecticides. Man had developed several transgenic crops by introducing these genes from bacteria to crop plants such as Bt cotton, Bt corn, tomato, etc.

5. What is gene therapy ? Illustrate using the example of adenosine deaminase (ADA) deficiency.

✓ Gene therapy is a collection of methods, that allows correction or replacement of a defective gene. Correction of a genetic defect involves delivery of a normal gene into the individual's embryo to take over the function of the non-functional gene. ADA deficiency was treated in a 4 year old girl. This disorder is caused by the deletion of the gene for the enzyme. The lymphocytes from the blood of the patient are grown in a culture *in vitro*. A functional ADA cDNA (using retroviral vector) is introduced into lymphocytes, such lymphocytes are introduced back into the blood of the patient. But the patient requires periodic infusion of such genetically engineered lymphocytes. If the gene isolated from marrow cells is introduced in cells in the early stage, it could be a permanent cure.

6. Diagrammatically represent the experimental steps in cloning and expressing a human gene (say the gene for growth hormone) into a bacterium like *E. coli* ?

✓ Refer to Fig. 12.10. Diagram showing steps involved in cloning and expressing a hormone gene for growth hormone into *E. coli*.

7. Can you suggest a method to remove oil (hydrocarbon) from seeds based on your understanding of rDNA technology and chemistry of oil ?
✓ The genes for the formation of oil in the seed should be identified. The appropriate genes should be removed with the help of restriction endonucleases. Such DNA should then be treated with DNA ligases to make seal DNA at the broken ends. Such DNA should then be treated with DNA medium will differentiate into a new plant whose seeds will not have oil in them.
8. Find out from internet what is golden rice.
✓ Golden rice is a variety of rice (*Oryza sativa*) produced through genetic engineering to biosynthesize the precursors of β -carotene (provitamin A). Golden rice 2 has 23 times more provitamin A and its deficiency leads to childhood blindness.
Golden rice was designed to produce β -carotene, a precursor of vitamin A in the part of rice that people eat, the endosperm. The rice plant can naturally produce β -carotene which is carotenoid pigment that occurs in the leaves and is involved in photosynthesis. However, the plant does not normally produce the pigment in the endosperm since photosynthesis does not occur in the endosperm. Golden rice was created by transforming rice with beta-carotene biosynthesis genes *psy*, *crt 1* and *lyc* gene.
9. Does our blood have proteases and nucleases ?
✓ No, our blood does not have proteases and nucleases.
10. Consult internet and find out how to make orally active protein pharmaceutical. What is the major problem to be encountered ?
✓ Proteins which have short half lives are generally not orally active and are poorly absorbed. This is due to fact that peptides are metabolically unstable and under physiological conditions, they are not absorbed orally and do not make good drug candidate.
So, the proteins are redesigned at the genetic level by the site directed mutagenesis or derivatised chemically to improve their therapeutic potential. The active sites of some of the larger proteins that are free of liable peptide bonds can be given orally.

TEXT QUESTIONS

One Mark Questions (With Answers)

1. How many polypeptides are found in human insulin ?
✓ Two
2. Name a popular recent technique, which is used for detecting the presence of pathogen/virus in an organism.
✓ ELISA
3. Name the two drugs that were earlier produced by sacrificing animals, but are now produced using biotechnology.
✓ Insulin, Interferon.
4. How many amino acids are present in insulin ?
✓ 51 aminoacids.
5. Name the bacterium, that is first used as biopesticide.
✓ *Bacillus thuringiensis*.
6. Name a biopesticide obtained from Neem (*Azadirachta indica*).
✓ Azadirachtin. (Haryana Board 2001)
7. Which transgenic crop was the first to be approved for commercial cultivation in India.
✓ Bt cotton.
8. Name any two free-living nitrogen fixing bacteria.
✓ *Azotobacter*, *Beijerinckia*.
9. What is DNA deficiency ? Which disease is associated with it ?
✓ Adenosine deaminase (ADA) deficiency is associated with (SCID) severe combined immunodeficiency (SCID)
10. Which technique do you suggest to detect suspected cancer patients ?
✓ Polymerase Chain Reaction (PCR).

11. Who helped to get patent for insecticidal properties of neem ?
✓ Vandana Shiva
12. Write the name of toxic protein secreted by *Bacillus thuringiensis*.
✓ Cry protein
13. Name the company which started selling human insulin in 1983.
✓ Eli Lilly.
14. In Insulin molecule which bond joins chain A and Chain B together ?
✓ Disulphide bond.
15. Name the World's first genetically modified non-human primate.
✓ A monkey named ANDI
16. Who discovered insulin and from where ?
✓ Sir Edward Sharpy-Shafer (1916) from islets of Langerhans.
17. Who observed that the fungus *Rhizopus stolonifer* could bring about hydroxylation of steroids ?
✓ Murray and Peterson (1950).
18. Name the first organic acid produced by microbial fermentation.
✓ Lactic acid.
19. What is the main function of RNA interference ?
✓ It is to prevent infestation.
20. When does the Bt cotton was commercially planted ?
✓ Bt cotton was commercially planted for the first time in 1996/97 in Australia and U.S.A.
21. Which enzyme is most commonly used for the crop improvement in genetic engineering ?
✓ The enzyme restriction endonucleases is most commonly used for crop improvement in genetic engineering.
22. Write the scientific name of the nematode that attacks the roots of tobacco plants.
✓ *Meloidogyne meognita*
23. What is 'probe' ?
✓ It is a single stranded DNA or RNA tagged with a radio-active molecule, which is complementary to the DNA in a clone of cells.
24. Name the first transgenic cow.
✓ Rosie
25. Name the bacterium that is used as a vector to insert genes in crop plants.
✓ *Agrobacterium tumefaciens*.
26. Expand GEAC.
✓ Genetic Engineering Approval Committee
27. Mention two objectives of setting up GEAC by our Government. (CBSE 2016)
✓ (i) Validity of GM research (ii) Safety of introducing GM-Organisms for public services.
28. What are *cry* genes ? In which organisms are they present ? (CBSE 2017)
✓ '*cry* genes' are genes found in *Bacillus thuringiensis*, a bacterium. These genes encode for protein crystals, that contain a toxic insecticidal protein (Bt toxin).
29. What is biopiracy? (CBSE 2017)
✓ Biopiracy is the commercial exploitation or patenting of biological resources of a nation by some organisation or company without proper authorisation from concerned country.

Two Mark Questions (With Sample Answers)

1. (A) Write name of the first transgenic crop in India.
(B) Insulin is extracted from which microorganism ?
✓ (A) A transgenic crop is a crop that contains a transgene i.e., a foreign gene is introduced and stably integrated into the host DNA. The name of first transgenic crop produced in India is Tobacco (*Nicotiana tabacum*).
(B) Insulin producing genes from the human being have been introduced into the bacteria - *Escherichia coli*. The genetically modified bacterium *E. coli* produces insulin called Humulin. This insulin is extracted from *E. coli* for clinical use.
2. Explain the following term in one or two sentences — bio-fortified foods.
✓ **Bio-fortified foods.** With the help of genetic engineering techniques biotechnologists have

developed plants which are rich in nutritional content. These are potato with increased starch content upto 20—40%, Tomato with delayed ripening, golden rice which is rich in vitamin A.

3. Even though green revolution has succeeded in the production of food supply yet the farmers prefer to use genetically modified crops. Why ?

✓ The success of green revolution has been due to the use of improved crop varieties and use of better management practices and use of agrochemicals. The agrochemicals are expensive and increase in yield with existing varieties are not, possible using conventional breeding. So, the farmers are using genetically modified crops where minimum use of fertilizers and chemicals takes place and their harmful effects on the environment are reduced.

4. What is sustainable agriculture ?

✓ Sustainable agriculture is that which would use renewable resources, cause the minimum pollution and maintain the optimum yields. Any development, which reduces the use of non-renewable resources and level of pollution, enhances the sustainability of agriculture.

5. How does transgenic crops technique differ from normal breeding activities ?

Transgenic Crops Technique	Normal Breeding Activities
1. In this technique, any gene can be used for transfer.	1. In normal breeding, only those genes can be used that are present in such species that can be hybridized with them.
2. Change in genotype can be controlled.	2. Changes cannot be controlled and occur in all those traits for which the parents used in hybridization differ from each other.

6. List the three options that can be considered for increasing food production.

✓ (i) Agro-chemical based agriculture ; (ii) Organic agriculture and (iii) Genetically engineered crop based agriculture.

7. Name the three techniques which are used for the purpose of early diagnosis.

✓ (i) Recombinant DNA technology (ii) Polymerase Chain Reaction (PCR). (iii) Enzyme linked Immuno-Sorbent Assay (ELISA).

8. Name at least three therapeutically important products obtained through recombinant genetic engineering.

✓ (i) **Vaccines**. Prevention of diseases like hepatitis B, herpes and meningitis etc.

(ii) **Human Insulin (hormone)**. Treatment of insulin dependent diabetes.

(iii) **Erythropoietin**. Treatment of pathogenic viral infections, cancer.

9. On what principle ELISA test is based ?

✓ **ELISA** is based on the principle of Ag Ab reaction.

10. What are limitations of ELISA test ?

✓ **Limitations**. (i) ELISA test shows the reasonable degree of false positivity and fails to detect about 1.5 percent cases of true possibility. (ii) The sign of the presence of HIV-virus is detected after few weeks. So, it creates difficulty in diagnosis and treatment of the HIV.

11. Name three diseases against which gene therapy has proved successful.

✓ Gene therapy has proved successful in treating diseases like sickle cell anaemia, hemophilia and Tay-Sach's. Gene therapy in sperm and ovum is now being done to perform *in vitro* fertilization (IVF).

12. Explain the role of TI plasmids in biotechnology.

(CBSE 2011)

13. Biopiracy should be prevented. State why and how.

(CBSE 2011)

14. Describe the gene therapy procedure for ADA- deficient patient.

(CBSE 2013)

15. (a) Why are transgenic animals so called ?

(b) Explain the role of transgenic animals in (i) Vaccine safety and (ii) Biological products with the help of an example each.

(CBSE 2013)

Three Mark Questions

- What are transgenic animals ? Why are these animals being produced ?
- How is Bt cotton made to attain resistance against bollworm ?

3. Name the pest that destroys the cotton bolls. Explain the role of *Bacillus thuringiensis* in protecting the cotton crop against the pest to increase the yield. (CBSE 2013)
4. How did the process of RNA Interference help to control the nematode from infecting roots of tobacco plants? Explain. (CBSE 2014)
5. Describe any three potential applications of genetically modified plants. (CBSE 2015)
6. How did an American company, Eli Lilly use the knowledge of rDNA technology to produce human insulin? (CBSE 2015)
7. How has RNAi technique helped to prevent the infestation of roots in tobacco plants by a nematode *Meloidogyne incognita*? (CBSE 2016)
8. Explain the various steps involved in the production of artificial insulin. (CBSE 2017)
9. Why do lepidopterans die when they feed on Bt cotton plant? Explain how does it happen. (CBSE 2017)

Five Mark Questions

1. Describe briefly the structure of insulin. How is genetically engineered insulin synthesized?
2. 'Biotechnology can greatly promote human welfare, but it can also be misused to increase human sufferings'. Comment on the statement with the help of suitable examples.
3. *Bacillus thuringiensis* has great potential in biological control of pests. Discuss.
4. (a) How has biotechnology helped in producing *Meloidogyne incognita* resistant tobacco plant? (CBSE 2010)
(b) Why does this nematode die on eating such a GM plant?
5. (a) Explain the effect of deletion of the gene for ADA in an individual. (CBSE 2010)
(b) How does the gene therapy help in this case.
6. Name and describe the technique that will help in solving a case of paternity dispute over the custody of a child by two different families. (CBSE 2010)
7. Write about the practical applications of genetic engineering.
8. (a) Name the technique used for separation of DNA fragments.
(b) Write the type of matrix used in this technique.
(c) How is the separated DNA visualised and extracted for use in recombinant technology? (CBSE 2010)
9. (a) Name the source from which insulin was extracted earlier. Why is this insulin no more in use by diabetic people?
(b) Explain process of synthesis of insulin by Eli Lilly Company. Name the technique used by the company.
(c) How is the insulin produced by human body different from the insulin produced by the above mentioned company? (CBSE 2011)
10. (a) Tobacco plants are damaged severely when infested with *Meloidogyne incognita*. Name and explain the strategy that is adopted to stop this infestation.
(b) Name the vector used for introducing the nematode specific gene in tobacco plant. (CBSE 2012)
11. Name the genes responsible for making Bt cotton plants resistant to bollworm attack. How do such plants attain resistance against bollworm attacks? Explain. (CBSE 2012)

Value Based Questions (With Answers)

1. David consulted his friend in a agriculture university for better quality of tomato. His friend suggested him to grow transgenic tomatoes with delayed ripening genes. These tomatoes would not decay if stored for some time.

Read the above passage and answer the following questions :

(i) What are transgenics?

(ii) How are transgenic tomatoes produced?

(iii) What is the importance of transgenic tomato?

✓ (i) The organisms which contain functional foreign genes, are called transgenics.

(ii) Transgenic tomatoes are produced by introduction of genes into their genome by genetic engineering from another species.

(iii) Transgenic tomatoes have delayed ripening property. Hence they can be stored for long period.

2. Rohit saw a big tree at the base of which were present numerous tumour-like structures. He asked the following questions from his biology teacher
- What are these tumour-like structures called ?
 - How are these tumours formed ?
 - Which is called natural genetic engineer ?
- ✓ (i) Crown gall tumours.
 (ii) These are formed by intergration of a segment of DNA of the bacterium *Agrobacterium tumefaciens* into the host DNA.
 (iii) *Agrobacterium tumefaciens* — because genes carried by its plasmid produce effect in several parts of the plant.
3. Suresh's grandfather read in the newspaper about golden rice, BT cotton and Transgenic bananas. He asked Suresh to get more information from his teacher about these crops.
 Read the above passage and answer the following questions :
- What is golden rice and what is its importance.
 - Expand BT. What is BT Cotton ?
 - What is the importance of transgenic bananas ?
- ✓ (i) Golden rice is variety of rice which is rich of vitamin A. It is very useful for poor rice eating human population which generally suffers from vitamin A deficiency.
 (ii) *Bacillus thuringiensis* (BT). BT cotton is genetically modified cotton.
 (iii) Transgenic bananas act as edible vaccines to protect children against diarrhoea.
4. Renuka's father is suffering from diabetes and is dependent on insulin for diabetes treatment. Earlier it was obtained from animals and was costly but now it is cheaper and easily available. It is due to biotechnology.
 Read the above passage and answer the following questions :
- What is the role of insulin ?
 - How many aminoacids are found in human insulin.
 - Who worked out molecular structure of insulin ?
 - Which company first prepared insulin.
- ✓ (i) Insulin regulates sugar level in the blood.
 (ii) 51 aminoacids arranged in two polypeptide chains, A having 21 aminoacids and B with 30 aminoacids.
 (iii) Sanger
 (iv) Eli Lilly, an American company

Multiple Choice Questions (With Answers)

- (1) *Cry II Ab* and *Cry I Ab* produce toxins that control (a) cotton bollworms and corn borer respectively (b) corn borer and cotton bollworms respectively (c) tobacco budworms and nematodes respectively (d) nematodes and tobacco budworms respectively (e) corn borer and tobacco budworms respectively (Kerala PMT 2010)
- (2) The technique of DNA finger printing was initially developed by (a) Ian Wilmut (b) Hargobind Khorana (c) Jacques Monod (d) Alec Jeffreys (e) Francois Jacob. (Kerala PMT 2010)
- (3) First genetically modified plant commercially released in India is (a) golden rice (b) slow ripening tomato (c) Bt-brinjal (d) Bt-cotton. (WB JEE 2010)
- (4) Salt tolerant transgenic has been developed for (a) brinjal (b) grape (c) potato (d) tomato. (AMU 2010)
- (5) Breeding for disease resistance requires (a) a good source of resistance (b) planned hybridisation (c) disease test (d) all of the above. (Orissa JEE 2010)
- (6) Genetic engineering has been successfully used for producing (a) transgenic mice for testing safety of polio vaccine before use in humans (b) transgenic models for studying new treatments for certain cardiac diseases (c) transgenic cow-Rosie which produces high fat milk for making ghee (d) animals like bulls for farm work as they have super power. (CBSE PMT Prelims 2010)
- (7) Some of the characteristics of Bt cotton are (a) long fibre and resistance to aphids (b) medium-yield, long fibre and resistance to beetle pests (c) high yield and production of toxic protein crystals which kill dipteran pests (d) high yield and resistance to bollworms. (CBSE PMT Prelims 2010)
- (8) Which one of the following is now being commercially produced by biotechnological procedures ? (a) nicotine (b) morphine (c) quinine (d) insulin. (CBSE PMT Mains 2010)

- (9) Which of the following is produced by genetical engineered bacteria ?
(a) thyroxine (b) insulin (c) glucagon (d) ADH. (AFMC 2010)
- (10) *Bacillus thuringiensis* is used to control (a) bacterial pathogens (b) fungal pathogens (c) nematodes (d) insect pests. (DUMET 2010)
- (11) The main aim of the human genome project is (a) to introduce new genes into humans (b) to identify and sequence all the genes present in human DNA (c) to develop better techniques for comparing two different human DNA samples (d) to remove disease causing genes from human DNA. (Karnataka CET 2010)
- (12) Some of the steps involved in the production of humulin are given below. Choose the correct sequence
(i) Synthesis of gene (DNA) for human insulin artificially (ii) Culturing recombinant *E.coli* in bioreactors
(iii) Purification of humulin (iv) Insertion of human insulin gene into plasmid (v) Introduction of recombinant plasmid into *E.coli* (vi) Extraction of recombinant gene product from *E.coli*.
(a) ii, i, iv, iii, v, vi (b) i, iii, v, vi, ii, iv (c) i, iv, v, ii, vi, iii (d) iii, v, ii, i, vi, iv. (Karnataka CET 2010)
- (13) To meet the demands of the society, *in vitro* production of a large number of plantlets in a short duration is practised in floriculture and horticulure industry today. This is called (a) hybridoma technology (b) somaclonal variation (c) somatic hybridization (d) micropropagation. (Karnataka CET 2010)
- (14) *Bacillus thuringiensis* forms protein crystals which contain insecticidal protein. This protein (a) binds with epithelial cells of midgut of the insect pest ultimately killing it (b) is coded by several genes including the gene *cry* (c) is activated by acid pH of the foregut of the insect pest (d) does not kill the carrier bacterium which is itself resistant to his toxin. (AIPMT (Mains) 2011)
- (15) Consider the following statements (A–D) about organic farming (a) utilizes genetically modified crops like *Bt* cotton (b) uses only naturally produced inputs like compost (c) does not use pesticides and urea (d) produces vegetables rich in vitamins and minerals.
Which of the above statements are correct ? (a) B, C and D (b) C and D only (c) B and C only (d) A and B only. (Karnataka CET 2011)
- (16) *Bt* brinjal is an example of transgenic crops. In this, *Bt* refers to (a) *Bacillus tuberculosis* (b) biotechnology (c) β carotene (d) *Bacillus thuringiensis* (Karnataka CET 2011)
- (17) Which one of the following bacteria is used for production of transgenic plants ? (a) *Escherichia coli* (b) *Bacillus thuringiensis* (c) *Staphylococcus aureus* (d) *Agrobacterium tumefaciens*. (West Bengal JEE 2011)
- (18) Biolistic technique is used in (a) tissue culture process (b) gene transfer process (c) hybridization process (d) germplasm conservation process. (West Bengal JEE 2011)
- (19) The thermostable enzymes, '*Taq*' and '*Pfu*', isolated from thermophilic bacteria are (a) RNA polymerases (b) DNA polymerases (c) restriction endonucleases (d) DNA ligases. (AMU (Medical) 2011)
- (20) During the processing of the prohormone "proinsulin" into the mature "insulin" (a) C-peptide is added to proinsulin (b) C-peptide is removed from proinsulin (c) B-peptide is added to proinsulin (d) B-peptide is removed from proinsulin. (AMU (Medical) 2011)
- (21) The *Bt* toxin is not toxic to human beings because (a) the pro *Bt* toxin activation requires temperature above human body temperature (b) the *Bt* toxin recognizes only insect-specific targets (c) the *Bt* toxin formation from pre *Bt* toxin requires pH lower than that present in human stomach (d) conversion of pro *Bt* toxin to *Bt* toxin takes place only in highly alkaline conditions. (AMU (Medical) 2011)
- (22) Alec Jeffreys developed the DNA fingerprinting technique. The probe he used was (a) ribozyme (b) sex chromosomes (c) SNP (d) rDNA (e) VNTR. (Orissa JEE 2011)
- (23) Consumption of which one of the following foods can prevent the kind of blindness associated with vitamin 'A' deficiency ? (a) Flaver Savr tomato (b) Canolla (c) Golden rice (d) *Bt*-Brinjal. (CBSE PMT (Prelims) 2012)
- (24) What is it that forms the basis of DNA fingerprinting ? (a) The relative proportions of purines and pyrimidines in DNA (b) The relative difference in the DNA occurrence in blood, skin and saliva (c) The relative amount of DNA in the ridges and grooves of the fingerprints (d) Satellite DNA occurring as highly repeated short DNA segments. (CBSE PMT Mains 2010, 2012)
- (25) Basic principle of developing transgenic plants and animals is to introduce the gene of interest into the nucleus to (a) somatic cell (b) vegetative cell (c) germ cell (d) body cell. (West Bengal JEE 2012)
- (26) In plant tissue culture, the callus tissues can be regenerated into complete plantlets primarily by altering the concentration of (a) sugars (b) vitamins (c) amino acids (d) hormones. (West Bengal JEE 2012)

- (27) The first clinical gene therapy was given for treating (a) diabetes mellitus (b) chicken pox (c) rheumatoid arthritis (d) adenosine deaminase deficiency (CBSE PMT Mains 2012)
- (28) Tobacco plants resistant to a nematode have been developed by the introduction of DNA that produced (in the host cells) (a) both sense and anti-sense RNA (b) a particular hormone (c) an antifeedant (d) a toxic protein (CBSE PMT Mains 2012)
- (29) In genetic engineering, the antibiotics are used (a) as selectable markers (b) to select healthy vectors (c) as sequences from where replication starts (d) to keep the cultures free of infection (CBSE PMT Mains 2012)
- (30) Golden rice is rich in (a) vitamin B (b) vitamin A (c) both (a) and (b) (d) none of these. (Odisha JEE 2012)
- (31) The gene that encodes for BT protein specific to cotton bollworm is (a) Cry I AC (b) Cry II Abc (c) Cry II AC (d) Cry II Ab. (HP PMT 2012)
- (32) RFLP analysis is a technique that (a) uses hybridization to detect specific DNA restriction fragments in genomic DNA (b) measures the transfer frequency of genes during conjugation (c) is used to detect genetic variations at protein loci (d) is used to amplify genes for producing useful products. (HP PMT 2012)
- (33) In case of *Bacillus thuringiensis*, *Bacillus* itself is not killed by the toxic protein crystals produced by it because Bt toxin (a) protein is not produced in the *Bacillus* (b) cannot cause any damage to *Bacillus* (c) protein is produced in very less amount in the *Bacillus* (d) exists as the inactive toxin. (J & K CET 2013)
- (34) Which of the following techniques is used to make numerous copies of a specific segment of DNA quickly and accurately ? (a) Translation (b) Transcription (c) Polymerase chain reaction (d) Ligase chain reaction. (J & K CET 2013)
- (35) Which of the following recent techniques is used for separating fragments of DNA ? (a) Eastern blotting (b) Northern blotting (c) Southern blotting (d) Western blotting. (J & K CET 2013)
- (36) Which of the following Bt crops is being grown in India by the farmers ? (a) Brinjal (b) Soybean (c) Maize (d) Cotton. (NEET 2013)
- (37) Crygene is obtained from (a) *Agrobacterium tumefaciens* (b) *Bacillus thuringiensis* (c) *Rhizobium leguminosarum* (d) *Rhizobium phaseoli*. (Maharashtra CET 2014)
- (38) Which site of the RNA pairs through hydrogen bonding with the triplet codes on mRNA? (a) Codon (b) 5' end of tRNA (c) 3' end of tRNA (d) Anticodon (e) Amino acid acceptor end. (Kerala PMT 2014)
- (39) Insect pest resistant *Bt*-cotton plant was developed using (a) somaclonal variation (b) micropropagation (c) somatic hybridization (d) transgenic technology. (WB JEE 2014)
- (40) Kyoto protocol is a multination international treaty for (a) phasing out greenhouse gases (b) controlling ozone destroying substances (c) management of hazardous wastes (d) conservation of biodiversity. (WB JEE 2014)
- (41) RNA interference which is employed in making tobacco plant resistant to *Meloidogyne incognita* is essentially involved in (a) preventing the process of replication of DNA (b) preventing the process of translation of mRNA (c) preventing the process of splicing of hnRNA (d) preventing the process of transcription. (Karnataka CET 2014)
- (42) The first human hormone produced by recombinant DNA technology is (a) insulin (b) estrogen (c) thyroxin (d) progesterone. (AIPMT 2014)
- (43) Golden rice is a genetically modified crop plant where the incorporated gene is meant for biosynthesis of (a) vitamin-B (b) vitamin-C (c) omega-3 (d) vitamin-A. (AIPMT 2015)
- (44) Select the wrong statement. (a) Human Insulin is being commercially produced from a transgenic species of *Escherichia coli* (b) The genetically modified *Bacillus thuringiensis* is used as biopesticide on the commercial scale (c) Human protein, alpha-1-antitrypsin is used to treat emphysema (d) The first transgenic cow, Rosie, produced alpha lactalbumin, enriched milk. (e) *Bt* toxin genes *cryIAC* control the corn borer. (Kerala PMT 2015)
- (45) The microbial biocontrol agent for butterfly caterpillar is (a) *Bacillus thuringiensis* (b) *Saccharomyces* (c) *Staphylococcus* (d) *Cyanobacteria*. (Kerala PMT 2015)
- (46) A transgenic food crop which may help in solving the problem of night blindness in developing countries is (a) Golden rice (b) Flavr Savr tomatoes (c) Starlink maize (d) *Bt* soybean. (J & K CET 2015)

- (47) Which part of the tobacco plant is infected by *Meloidogyne Incognita* ? (NEET-I-2016)
 (a) Leaf (b) Stem (c) Root (d) Flower.
- (48) The two polypeptides of human Insulin are linked together by (NEET-I-2016)
 (a) Phosphodiester bond (b) Covalent bond (c) Disulphide bridges (d) Hydrogen bonds.
- (49) Which kind of therapy was given in 1990 to a four-year-old girl with Adenosine Deaminase (ADA) deficiency ? (NEET-II-2016)
 (a) Gene therapy (b) Chemotherapy (c) Immunotherapy (d) Radiation therapy.

Assertion and Reason Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—

- (a) If both A and R are true and R is the correct explanation of A
 (b) If both A and R are true and R is not the correct explanation of A
 (c) If A is true but R is false
 (d) If both A and R are false.

- Assertion:** Sharbati Sonora was developed from Maxican wheat variety.
Reason: It becomes possible by hybridization process.
 A B C D
- Assertion:** Insulin is said to be anabolic hormone.
Reason: Failure of insulin secretion causes diabetes.
 A B C D
- Assertion:** Intercropping checks the population of insects.
Reason: Plant pests can be controlled biologically by their natural parasites and pathogens.
 A B C D
- Assertion:** Interferons are effective against viruses.
Reason: Proteins which can be synthesized only by genetic engineering are effective against viruses.
 A B C D
- Assertion:** Dr. Swaminathan has major contribution in breeding of wheat.
Reason: He developed "Sharbati Sonora" from "Sonora 64".
 A B C D

ANSWERS

Multiple Choice Questions

- (1) —a (2) —d (3) —d (4) —d (5) —d (6) —a (7) —d (8) —d (9) —b (10) —d
 (11) —b (12) —c (13) —d (14) —a (15) —c (16) —d (17) —d (18) —b (19) —b (20) —b
 (21) —c (22) —e (23) —c (24) —d (25) —c (26) —d (27) —d (28) —a (29) —a (30) —b
 (31) —d (32) —a (33) —d (34) —c (35) —c (36) —d (37) —b (38) —d (39) —d (40) —a
 (41) —b (42) —a (43) —d (44) —e (45) —a (46) —a (47) —c (48) —c (49) —a

Assertion Type Questions

1. —C 2. —B 3. —B 4. —C 5. —A

Ecology (Gk. *oikos*–home, *logos*–study) is the branch of biology that deals with the inter-relationship amongst organisms and interactions between organisms and their environment. Organisms interact with all the components of environments, namely atmosphere, hydrosphere and lithosphere.

The term ecology is believed to have been coined by Ernst Hackel (1869) though its first authentic use was made by Reiter (1885). Two other terms equivalent to ecology are **hexicology** and **ethology**. Ecological studies have undergone a lot of renaissance from natural history to biogeography to ecosystem ecology and now **global ecology** wherein the whole earth is considered to be a single ecological entity with a stress on changes in climatic regime, biodiversity, conservation and ecological sustainability. Study of ecology is important to strike a balance between development and maintenance of natural environment and its biotic communities, use and conservation of resources, solve local regional and global environmental problems.

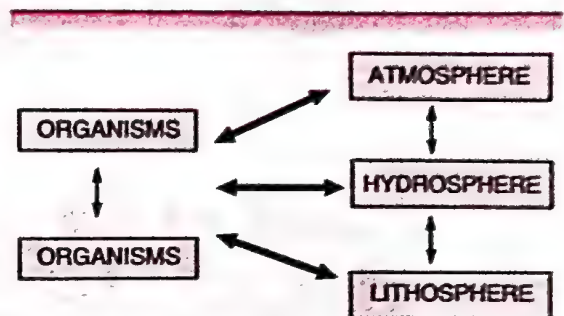


Fig. 13.1. Interaction of organisms with components of physical environment as well as other organisms.

Ecology has two main branches. (i) **Autecology/Species Ecology**. The study of reciprocal relationships between every stage of development of a population/species and its environment is called autecology. (ii) **Synecology**. It is the study of reciprocal relationships between composition, organisation and development of communities and their environment.

Levels of Ecological Organisation

Organisation is the arrangement and coordination of small components into larger components in a hierarchy where each level is formed of components of lower level and itself becomes constituent of still higher level. Biology is a field of study which deals with organisation at several levels in an ascending order of complexity starting from genes and other biomolecules, subcellular structures, cells, tissues, organs, organ systems, individual organism, population, biotic community, ecosystem, landscape, biome and biosphere. Hierarchy in organisation from the level of biomolecules to organismic level is called **biological hierarchy** or **biological organisation**. At every level of biological organisation, two questions will always arise, how and why, e.g., how does a bird sing or why does a bird sing? 'How' type questions seek the mechanism of a process or phenomenon while 'why' type questions seek the significance of the process. A bird is able to sing with the help of voice box and the vibrating bone. It sings in order to communicate with its mate especially during mating season. Similarly, why are night blooming flowers generally white? They become visible to pollinating moths. A number of such questions can be asked. How does a bee know which flower possesses nectar? Why does a cactus possess so many spines? How does a chick recognise her mother?

The hierarchy in the levels of organisation connected with ecological grouping of organisms is called **ecological hierarchy** or **ecological levels of organisation**. There are no sharp lines or breaks in the functional sense amongst various levels of ecological hierarchy as the same individual is a component of population, biological community as well as ecosystem.

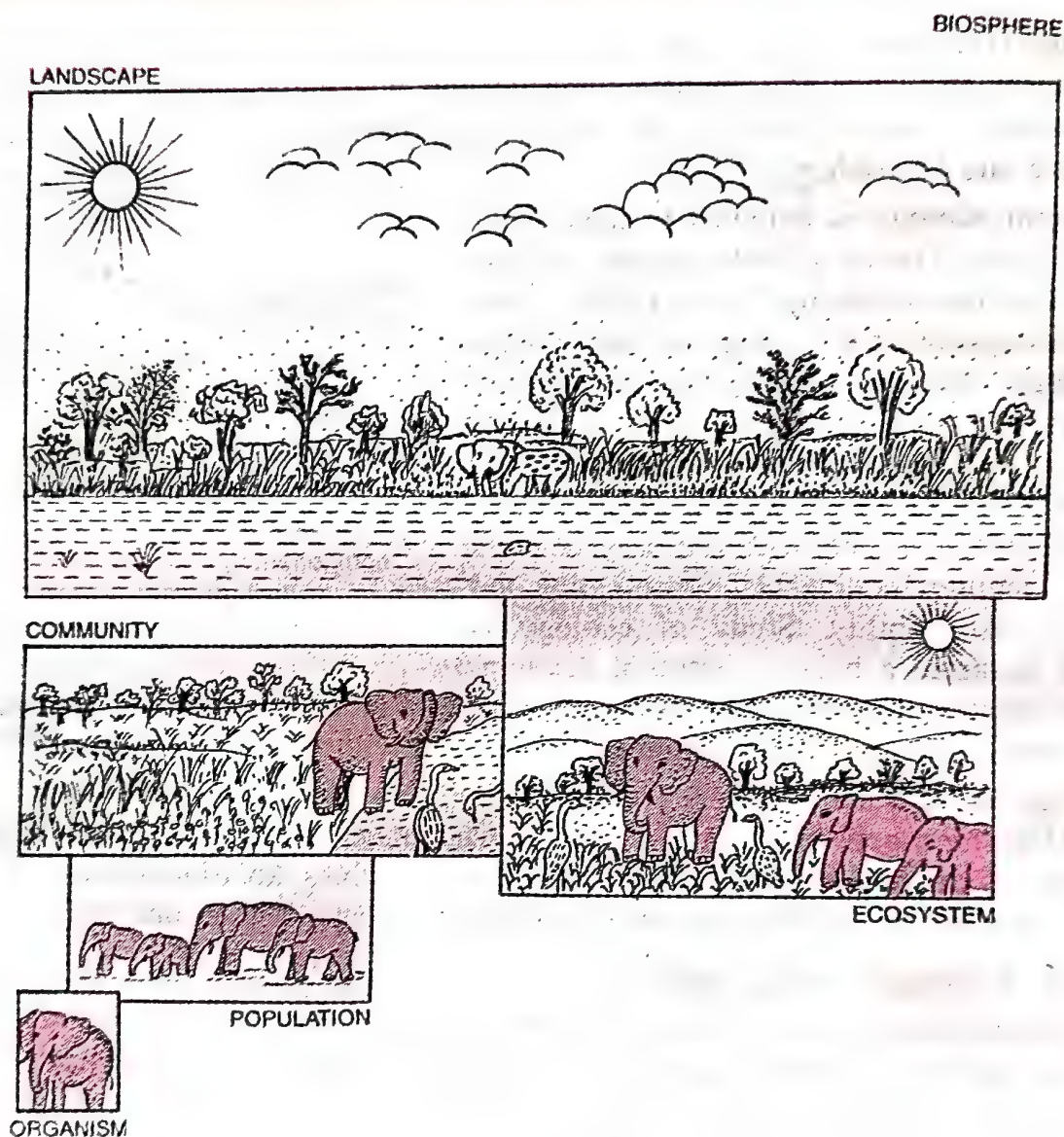


Fig. 13.2. Ecological levels of biological organisation.

1. **Individual (Organism).** It is distinct living entity or distinct package which carries out all life processes in its body, separate from those in other individuals. An individual is made up of one or more cells. It is capable of self repair and self regulation. Individual organism is the basic unit of **ecological hierarchy** as it continuously exchanges materials and information with its environment. New individuals develop from pre-existing ones. Hereditary characters are transferred during this process. The constituents of an individual cannot survive independently.

2. **Population.** It is a grouping of similar individuals in a particular geographical area or space. The different populations of the same organism present in particular geographical

areas are called **local populations/demes**. A local population adapted genetically to its particular environment is called **ecotype**. There may be several ecotypes of the same organism which show variations amongst them.

3. **Biological or Biotic Community**. It is an assemblage of populations of different species of plants, animals, bacteria and fungi which live in a particular area and interact with one another through competition, predation, mutualism, etc. Each biotic community has a specific composition and structure, e.g., pond community.

4. **Ecosystem**. It is a segment of nature consisting of a biological community and its physical environment both interacting and exchanging materials as well as energy, e.g., pond ecosystem.

5. **Landscape**. It is a unit of land distinguished by a natural boundary and having patches of different ecosystems, e.g., southern peninsula.

6. **Biome**. A large regional unit delimited by a specific climatic zone, having a particular major vegetation zone and its associated fauna, e.g., tundra desert, temperate deciduous forest, tropical rain forest, ocean.

7. **Biosphere**. It is biologically inhabited part of earth along with its physical environment consisting of lower atmosphere, land and water bodies.

Environment, Climate, Habitat and Niche

Environment. It is the sum total of all biotic (connected with living beings) and abiotic (connected with nonliving) factors, substances and conditions that surround and potentially influence organisms without becoming their constituent part. The various components of environment are interlinked as well as interdependent. They function at local, regional and global scale, e.g., microclimate (local climate), regional climate, global climate. Some components function as a **resource** while others work as **regulatory factors**.

Weather and Climate. The short term properties of atmosphere at a given place and time with respect to such conditions as heat, cold, sunshine, rain, cloud, wind, etc. is called **weather**. It varies from time to time at the same place and place to place at the same time. **Climate** is the **average weather** conditions of a particular region of earth or area with regard to temperature, rainfall, air pressure, seasonal variations and weather extremes. Temperature, rainfall, solar radiations and air pressure determine the climate of an area. The variations in climates develop due to differential duration, angle and intensity of solar radiations in different areas of the world, resulting in movement of winds and ocean currents.

Differences between Weather and Climate

Weather	Climate
1. It is a short term property of the atmosphere.	1. Climate is a long term property of the atmosphere.
2. Weather changes from place to place.	2. Climate is the same over a larger area.
3. Changes in weather occur from time to time.	3. Climate remains the same over a long period of time.
4. Weather changes with changes in any of the atmospheric factors and conditions.	4. Climate does not change in such circumstances as it represents the average of the factors and conditions.
5. Weather changes have little impact on flora and fauna of a place.	5. Climate determines the flora and fauna of a place.

Four climatic and vegetation zones have been recognised on the basis of mean temperature along the latitude.

Zone	Latitude	Mean Annual temperature	Winter	Vegetation
1. Tropical	0°—20°	Above 24°C	Nil	Tropical Forests
2. Subtropical	20°—40°	17°—24°C	Mild winter	Subtropical Deciduous Forests
3. Temperate	40°—60°	7°—17°C	Winter with occasional snow	Mixed coniferous Forests
4. Arctic and Antarctic	60°—80°	Below 7°C	Severe prolonged winter with abundant snow	Arctic vegetation

A similar but miniature climate and vegetation zonation occurs over mountains along the increasing altitude. A high mountain in tropical area will have all the four zones—tropical, subtropical, temperate and alpine (an equivalent to arctic/antarctic). A mountain in subtropical area will have only three zones (subtropical, temperate and alpine) while the one in temperate area would have only two zones (temperate and alpine).

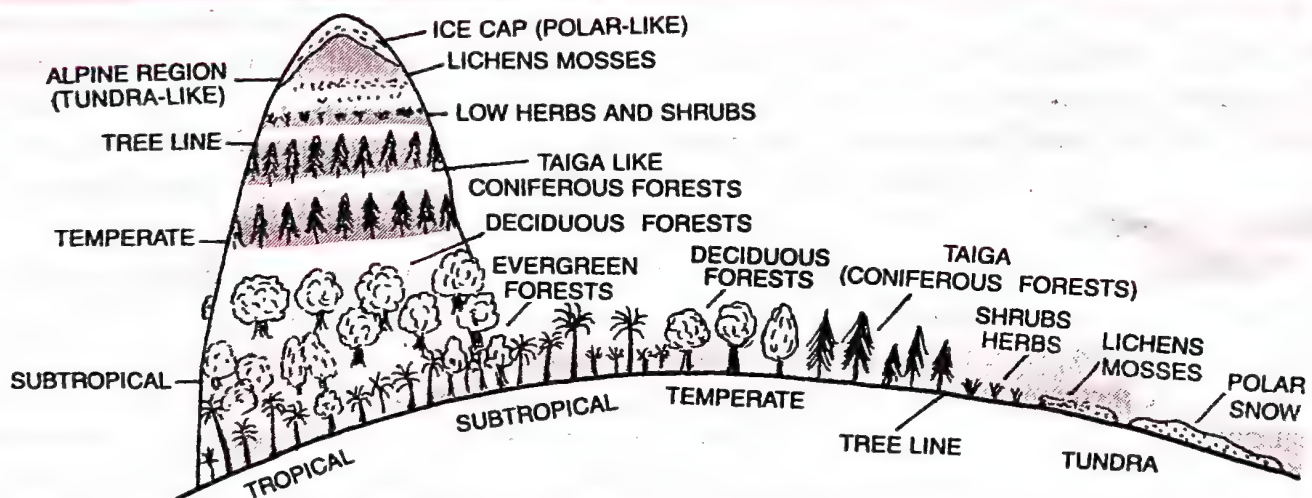


Fig. 13.3. Zonation in terrestrial vegetation.

However, variations occur in each zone due to changes in annual and seasonal precipitation. Therefore, vegetation and soil types are determined by two climatic factors, temperature and precipitation.

Microclimate (Microenvironment). It is the local variation of a climate that occurs in an area of limited size. Below a tree, temperature is higher than the surroundings in winter while it is lower during summer. Canopy of tall trees is exposed to strong light and high temperature during the day while plants occurring below them receive dim light, lower temperature and higher humidity.

Habitat. It is a specific place or locality delimited by a combination of factors, physical features and barriers where a community resides, e.g., pond, desert, river, valley, saline soil, etc. Plants and animals adapt themselves to specific conditions of their habitat, e.g., aquatic organisms, halophytes. The characteristic adaptations related to a particular habitat are not found in organisms of another habitat, e.g., plants of saline and nonsaline soils.

There are innumerable habitats on earth due to large scale regional and local variations in each climatic and vegetational zone. Some of them are favourable. Others are unfavourable. Some extreme and harsh habitats also support life, e.g., scorching desert of Rajasthan, rain soaked Meghalaya forests, torrential streams, high mountain tops, deep sea trenches, permafrost polar regions, boiling thermal springs, deep sea hydrothermal vents, stinking compost pits, etc. Human intestine is also a unique habitat for hundreds of species of microbes.

Microhabitat. It is a subdivision of the habitat having a specific property, e.g., forest floor, tree canopy, tree trunk, edge of a pond.

Niche or Ecological Niche (Fr. *nicher* —to nest; Grinnel, 1917). It is specific part of habitat occupied by individuals of a species which is circumscribed by its range of tolerance, range of movement, microclimate, type of food and its availability, shelter, type of predator, and timing of activity. Tadpole and adult frog occupy different ecological niches as the former is herbivorous aquatic while the latter is carnivorous amphibian. Water Bug and Water Boatman live in shallow edges of ponds but occupy different niches as the former is predator while the latter is scavenger. Both Owl and Cat feed on Shrews and Mice. They occupy the same niche because of being **ecological equivalents** though their habitats are different. In the same habitat, a common resource can be exploited by many species, e.g., nectar feeding, leaf eating. They are collectively called **guild**. Odum (1959) has called habitat an **address** and niche as **profession** of a species. A habitat supports a number of species. It also possesses numerous ecological niches. However, an ecological niche supports a single species. No two species occupy the same niche.

Differences between Habitat and Niche

Habitat	Niche
1. It is a specific place or locality where a community resides.	1. It is an ecological component of habitat which is delimited by functioning of an organism.
2. A habitat has a number of niches.	2. A niche does not have components.
3. Habitat supports a number of species.	3. Niche supports a single species.
4. A number of environmental variables occur in a habitat.	4. Niche has a specific set of environmental regimes.
5. A species does not change its habitat.	5. A species may live in more than one niche in different stages of its life cycle.

Biomes

Sun is the source of both light and temperature. Solar radiations fall vertically in tropical areas. They are oblique in temperate and polar regions (Fig. 13.4). Rotation of earth and the tilt of its axis causes seasonal changes. These variations together with variations in precipitation (rain and snow) produce major terrestrial biomes of the world (Fig. 13.5) — tropical forests, deciduous forests, coniferous forests, grasslands, desert, arctic and alpine tundra.

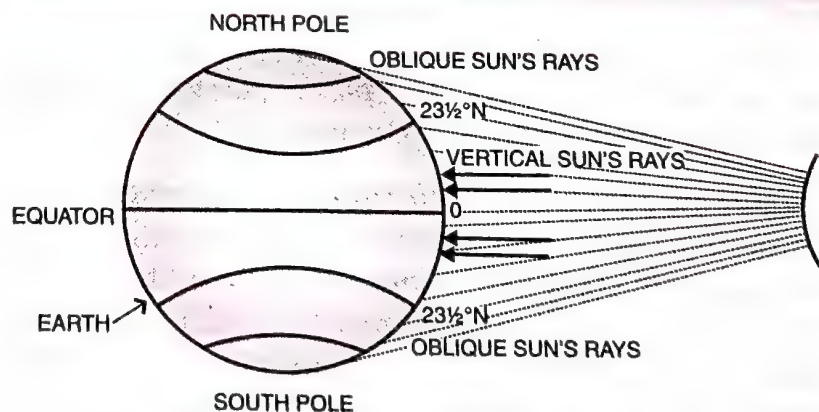


Fig. 13.4. Incidence of Sun's Rays. Note the sun rays falling vertically overhead the equator on spherical earth which produce high temperature. Oblique rays falling at the two poles give low temperature.

1. **Tundra** (Rus. *tundra* —arctic hill or north of timberline).

Location. It lies north of timberline or 60°N latitude below the polar ice. Tundra occupies some 8 million km² area of land mass extending across N. America, Europe and Asia. It occurs only in the arctic region and is, therefore, also called **arctic tundra**. Tundra is absent in the southern hemisphere because corresponding region is covered by antarctic region.

Physical Characteristics. The area receives very little precipitation, around 25 cm per year, mostly in the form of snow. The area is covered by snow for most part of the year. The climate is, therefore, extremely cold with a winter temperature -30°C to -40°C . Strong winds and snow storms are frequent. Summer is for short duration of 45–75 days. The highest summer temperature is 10°C . It is unable to melt snow except for the upper 10–20 cm. The remaining part of the soil is in permanently frozen (**permafrost**) condition. Alternate thawing and freezing of the upper layers produces cracks. The terrain is plain or with gentle slope but has numerous depressions or cracks where ponds, pools, marshes and bogs are formed during summer.

Life. Both vegetation and animal life exist in this biome, though very scarce.

Flora. Vegetation is thin. North tundra is often called **arctic desert** because it contains very sparse low growing vegetation devoid of any tree. Only those plants grow in tundra which either complete their life cycle in brief summer or can remain alive even when covered by snow for 8–10 months. They are shallow rooted as the subsoil is permanently frozen. Mosses and lichens show best development in the area. The common moss is *Sphagnum* (Bog Moss) and the most common lichen is *Cladonia* (Reindeer Moss). Other plants growing in tundra are grasses, sedges, heaths, a few shrubs, dwarf willows (*Salix species*) and dwarf birches (*Betula species*). The plants possess xerophytic characters. Leaves are often small and hairy. Their margins show folding.

Fauna. Amphibians and reptiles are absent from tundra. Arthropods (e.g., biting flies and mosquitoes) appear in summer. Common animals of tundra are warm blooded and have protective covering like feathers (birds) and hairy skins (mammals). Mammals have a thick layer of insulating fat below their skin. Main birds of tundra are snow owl and snow grouse. Important mammals of the area are polar bear, arctic hare, arctic fox, musk ox, caribou, reindeer, arctic wolf and weasels. Shore and water birds visit the area during summer. Some animals live in burrows or caves during winter and hibernate, e.g., polar bear. Others migrate in winter to less cold temperate areas, e.g., reindeer, caribow.

Tundra is a highly delicate and fragile biome. It takes a long period to recover from even a minor disturbance.

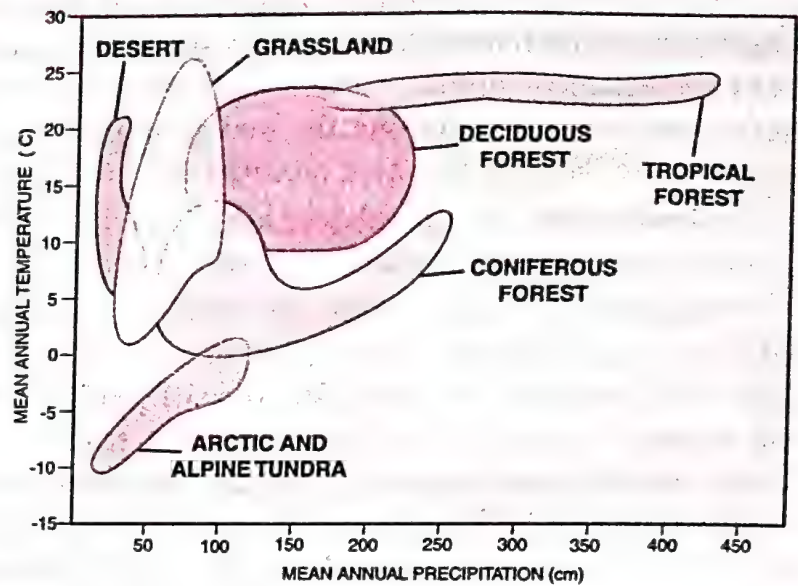


Fig. 13.5. Terrestrial biomes governed by temperature and precipitation.

Table 13.2. Climatic Conditions in Major Forest Types of India

S. No.	Forest Type	Mean Annual Temperature	Mean Annual Rainfall	Dry Months
1.	Tropical Rain Forest	23–27°C	200–350 cm	2–3
2.	Tropical Deciduous Forest	22–32°C	90–160 cm	6–8
3.	Temperate Broad Leaved Forest	6–20°C	100–250 cm	3–5
4.	Temperate Needle Leaved (Coniferous) Forest	6–15°C	50–170 cm	3–5

2. Temperate Needle Leaf or Coniferous Forests. Location. The biome occurs just south of tundra across north America, Europe and Asia. It is also found in the southern hemisphere (e.g., parts of New Zealand). Roughly 10% of the land mass is under Taiga.

Physical Characteristics. Precipitation is highly variable, 10–35 cm in drier parts and over 100 cm in wetter parts. It occurs both as rain as well as snow. Lakes and marshes are quite common in the wetter parts. The marshes bogs have cotton grass and *Sphagnum*. Winters are quite chilly with long dark nights. The average winter temperature does not exceed 6°C. Summers are pleasant with long hours of day light and an average temperature of less than 20°C. The growing season is for about 150 days.

Life. Life is fairly rich in this biome.

Flora. Dominant vegetation consists of evergreen conifers which are able to tolerate wide fluctuations of temperature, light and soil. They are Pine, Fir, Hemlock, Spruce, Juniper, Yew, Larch, Deodar (= Cedar). Where conditions are more favourable, dense coniferous forest is present with little light reaching the ground. The ground flora consists of herbs, ferns, mosses and lichens. The latter three also occur on trees and shrubs under humid conditions. Birch and Maple are found at several places. Vines and wild flowers are common.

Fauna. Animal community of the biome is represented by mouse, wolves, otters, beavers, elk, deer, raven, rabbit, hare, squirrels, pumas, lynx, grouse, jay, many species of insects etc. During winter many animals hibernate or migrate to warmer places. The area also receives reindeer and caribou from tundra during winter.

Himalayan Coniferous Forests. They are altitudinal forests which occur in the Himalayas at the altitude of 1700–3000m. They are **evergreen** because the needle shaped leaves of the coniferous plants persist for 2–7 years. Canopy of the trees is generally cone-shaped. Height is 30–35m or even more. The common trees are *Pinus wallichiana* (Pine), *Cedrus deodara* (Deodar), *Cupressus torulosa* (Cypress), *Picea smithiana* (Spruce) and *Abies pindrow* (Silver Fir). They are economically valued trees.

3. Temperate Deciduous Forest. Location. It is found in both the northern hemisphere (Canada, eastern U.S.A., north central Europe, eastern Asia) and southern hemisphere (New Zealand, eastern Australia). The forest occurs in some 18 million km² of temperate areas.

Physical Characteristics. The areas have warm summer and moderately cold winter. Annual precipitation lies between 75–150 cm.

Life. Plant and animal life is rich in the temperate deciduous forest—biome.

Flora. The dominant climax vegetation consists of broad-leaved hardwood (dicot) trees like Oak, Elm, Maple, Birch, Beech, Hickory, Magnolias, Poplars, etc. Shrubs are also

abundant. The trees and shrubs usually shed their leaves with the onset of autumn (hence also called fall). New leaves are produced in early spring. A few soft-wood trees (conifers) may occur at places interspersed with hardwood trees.

Where conditions are favourable, four-storeyed forest is formed. The top stratum is occupied by trees reaching a height of 30–40 m. There is an understorey of small trees, an intermediate stratum of shrubs and a ground stratum made of herbs, grasses, ferns, mosses and lichens. Vines are found here and there.

Fauna. The animal population, includes frogs, salamander, turtles, snakes, lizards, rabbits, hares, squirrels, opossums, foxes, racoons, deer, bear, thrushes, owls, sparrows and several song birds. In winter, some animals undergo hibernation or migrate to warmer areas.

Himalayan Temperate Broad Leaved Forests. They occur in the western Himalayas at an altitude of 1500–2400m, either alone or mixed with conifers. Himalayan temperate broad leaf forests are dominated by Oaks. Tree canopy is dense. Herbaceous layer is poorly developed. Grasses are generally absent. Epiphytes are abundant. The forests have upto four strata. Tree height is 25–30m. The common oaks of these forests are *Quercus semicarpifolia* (Brown or Khirsu Oaks), *Q. floribunda* (Tilonaj Oak), *Q. lanceginose* (Rianj Oak) and *Q. leucotrichophora* (Barj Oak). Himalayan Oaks differ from other Oaks in that they never become leafless so that the forests do not give a deciduous look but instead evergreen. Ofcourse peak leaf fall occurs during summer.

4. Tropical Rain Forest (Tropical Evergreen Forests). Location. Tropical rain forests are mainly found in central America, along Amazon and Orinoco rivers, South America, Congo river basin of Africa, Malagasy Republic and south east Asia including India. In India, tropical rain forests occur in Western Ghats, Assam and Andamans.

Physical Characteristics. The biome occurs in equatorial or sub-equatorial regions where both rainfall and warmth are abundant. Rainfall is above 140 cm/yr usually between 200–500cm/yr. It may be upto 1000 cm. Rain occurs through major parts of the year. Therefore, humidity is good. Plant growth is luxuriant. The forest is thick and almost impenetrable. As a result it is called **jungle**. The forests occupy about one-twelfth of the total land but possess more than half of the flora and fauna of the world. Diversity of life is so high that a hectare of the forest may have as many as 200 species of trees, 70–80% of all insects and 80–85% of all birds are known from tropical forests.

Standing crop biomass is highest though the soil is highly leached with low base content. Luxuriant plant growth is maintained by nutrient cycling.

Productivity of the biome is very high (12000 kcal/m²/yr as compared to 3000 kcal/m²/yr for temperate deciduous, 2000 kcal for taiga and only 200 kcal/m²/yr for tundra).

Life. Life is abundant in this biome. It has different varieties and number of plants and animals.

Flora. The vegetation shows **stratification**. Stratification is the grouping of plants in a forest into two or more well defined layers depending upon their height like tall trees, medium sized trees, small trees, bushes, herbs, etc. The different layers are called **strata** or **storeys**. Tropical rain forest is multistoreyed (Fig. 13.6) and mainly contains broad-leaved ever-green plants. There are a minimum of five storeys or strata or vegetation. The upper storey is occupied by very tall emergent trees (50 m or more). The canopy is open. The second storey is constituted by tall trees (35–40 m) which form a dense and closed canopy. There is an understorey or intermediate layer of small trees, a shrub layer and a ground layer of ferns, mosses and herbs. The forest floor receives very little sunlight. Epiphytic growth is rich due

to humidity. It includes orchids, lichens, mosses and ferns. Vines and lianas are abundant especially on the edges of the forests. The forest trees have buttressed trunks. Cauliflory or formation of flowers on stems and branches is common. The leaves of tall trees are leathery with drip tips for the flow of rain water.



Fig. 13.6. Stratification in a tropical forest.

Fauna. Each storey or stratum has different fauna.

Upper storeys have birds, insects, bats, monkeys, lemurs, tree frogs, lizards and anteaters. Ground fauna includes many snakes, some lizards, deer, forest goat, antelope, tapir, elephant, leopard, jaguar, etc.

In India the tropical rain forests are dominated by *Dipterocarpus* and *Hopea*. Other large sized trees are *Mesua*, *Artocarpus*, *Cinnamomum*, *Diopyros*, *Alstonia*, *Polyalthia*, *Toona*, *Calophyllum*, etc. The under storey trees are *Embllica*, *Callicarpa*, *Cordia*, *Randia* etc. Palms and bamboos also occur. Climbers and epiphytes are abundant. Ground flora consists of ferns, herbs and shade tolerant seedlings of dominant trees.

5. Tropical Deciduous Forests. Climate is warm with alternate wet and dry periods. Rainfall is 90–160cm. Vegetation includes broad-leaved trees which shed their leaves during dry season, e.g., *Butea*, *Bombax*, *Shorea*, *Dalbergia*, *Diospyros melanoxylon* (Tendu/kendu), *Buchanania lanzan* (Chiraunji), *Acacia catechu* (Khair). Famous Sal (*Shorea*), Teak (*Tectona*) and Sandal (*Santalum*) forests of India belong to this category. In India tropical deciduous forests occur in both plains and low hilly areas of North as well as South. In North-Western parts tropical deciduous forests merge into thorn forests. Canopy height is 10–20m. The forests are lush green with dense foliage and herbaceous layer during the rainy season. During dry seasons, leaf fall occurs and the herbaceous layer dries up. Forest fires can occur. Many trees possess thick fire resistant bark. Soil is rich in nutrients due to seasonal leaf fall and slow humification. Animal population is similar to evergreen tropical forests.

6. Chapparal (Mediterranean Scrub Forest). **Location.** The biome occurs in mediterranean area (hence mediterranean scrub forest), pacific coast of north America, Chile, south Africa and south Australia.

Physical Characteristics. It is a broad-leaved evergreen shrub forest of hard and thick-leaved small trees and shrubs which usually contain resin but are resistant to fires. The area has frequent bush fires during 'dry' summer. It receives humid air from nearby oceans which also keeps the temperature moderate. Rainfall is during winter only.

Life. Both plants and animals are adapted to long droughts.

Flora and Fauna. Both plants and animals are adopted to frequent and long periods of drought. The common plants of chapparal are *Arctostaphylos* (Manzita), Sage, *Carnithus*, *Adenostema*, (Cheemise), Oak and *Eucalyptus* (in Australia). Animals include rabbits, rats, chipmunks, deer, snakes, lizards, birds, tiger, etc.

7. Tropical Savannah (Savanna). It is warm climate plain with coarse grasses,

scattered shrubs and trees, seasonal rain (wet and dry periods) and frequent fire. Height of woody species is 1–8m. Savanna occurs in North Australia, India, Central and Southern Africa including east-central S. Africa. They are natural as well as anthropogenic. Indian savannas are largely anthropogenic being derived from tropical forests and maintained by grazing as well as fire. Availability of soil moisture determines composition and productivity. Root system of grasses is present in upper 30cm of soil while that of woody species penetrate to deeper horizons. Savannah is named after dominant tree like *Acacia*, *Phoenix*, *Eucalyptus*.

Common trees and shrubs of Indian savannas are *Acacia*, *Butea*, *Prosopis*, *Zizyphus* and *Capparis*. Common grasses are *Dichanthium*, *Schima*, *Cenchrus*, *Lasiurus*, *Imperata* and *Saccharum*. Many of them perform C_4 photosynthesis that is helpful in maintaining high productivity even under conditions of low soil moisture. Hoofed herbivores are quite common. Animals include Antelope, Zebra, Giraffe, Goat, Gazella, Rhino, Elephant, Fox, Wolf, Lion, Tiger, Kangaroo (in Australia).

8. **Grassland.** In grassland, grasses are dominant with nongraminaceous herbs mostly leguminous (maintain nitrogen fertility of soil), scattered bushes and occasional tree, e.g., **prairies** of U.S.A/Canada, **pampas** of South America, **steppes** of Eurasia, **tussocks** of Newzealand, **downs** of Australia and **veldts** of South Africa. There is hot summer, cold winter, seasonal 25–75cm rainfall. Rainfall is short of forming forests and more than the amount that induces desert formation. Grasses can be sod formers or grow in bunches. Height of grasses varies from a few centimetres to 1.5m in moist regions. Shoot biomass is 50–1000gm/m². Primary productivity is related to rainfall. Root system is extensive. Grazing and fire help maintain grassland and prevent woody species to invade the area. Fauna consists of Deer, Elk, Bison, Wolf, Prairie Dog, Bear, Bighorn Sheep, Rabbit, Mice, Budes, Coyote, Burrowing Owl.

Differences between Grassland and Savanna

Grassland	Savanna
1. It occurs in all types of climate.	1. Savanna is usually found in warm subtropical or tropical climate.
2. Trees are largely absent.	2. Trees occur scattered here and there.
3. Rainfall is low but periodic.	3. Rainfall may be more but dry periods are quite prolonged.
4. It consists of grasses and herbs. Shrubs are a few.	4. It consists of grasses, herbs, shrubs and a few trees.

9. **Desert Biome.** It occupies about 1/5 of land. It lacks rain (less than 25cm) due to either being present in **rain shadow** (area beyond high mountains which cut off clouds e.g., Tibet), lack of cloud intercepting mountains (e.g., Thar) or lying away from cloud seeding regions. e.g., Death Valley (Great Western Desert) of U.S.A., Sahara (Africa), Gobi, Arabian and Thar of Asia. Rajasthan lies in the Thar desert. Most of these lie around tropic of Capricorn and tropic of Cancer between 15°–35° latitude in both hemispheres. Desert can be **cold** (e.g., Tibet, Gobi) and **hot** (e.g., Thar, Sahara). In **true deserts**, rainfall is less than 12cm/year while in **extreme** desert it is even less than 7cm/yr. Whether is cold or hot, evaporation from desert exceeds 7–50 times the rainfall. Ground is sandy or rocky. Vegetation is sparse. It consists of three types of plants. (i) Ephemerals or short lived annual herbs which grow during period when sufficient moisture is available. (ii) Cacti and other succulent xerophytes (e.g., *Euphorbia* species) which store water. (iii) Deep rooted shrubs

and small trees which are able to obtain water from the water table, e.g., *Prosopis*, *Salvadora*, *Tamarix*. Common grass is *Cenchrus*. Shrubs include *Aerua* and *Echinops*. Tall succulents, mostly cacti, are abundant in deserts. Animals are Kangaroo/Desert Rat, Hare, Fox, Jackal, Cat, Rattle Snake, Coral Snake, Lizards (Gila Monster, Horned Lizard), Spiders, Scorpions, Locusts, Ants, Wasps, and a number of birds like Swifts, Swallows, Quails, Doves, etc. Camel is adapted to desert conditions as it can protect its eyes and nostrils from dust, has insulated spreading feet, and is capable of tolerating dehydration upto 40% with highly reduced urine output.



Fig. 13.7. A desert scene.

10. Altitudinal Biomes. On the basis of broad climatic regimes, only four types of terrestrial biomes are present—tropical rain forest, temperate deciduous, taiga and tundra. Other types are variations of these biomes. All these latitudinal biomes can be observed on the high mountain ranges found in tropical areas like Himalayas, Andes and Rockies. The four latitudinal terrestrial biomes are telescoped into altitudinal biomes each extending a few hundred metres in height from base to below the snow line. The basal part is called terai in India. It possesses tropical forest. The same is succeeded by deciduous forest, coniferous forest and tundra. High mountains growing in warm temperate areas do not have tropical forests at the base. Instead they begin with temperate deciduous forest. Low altitude mountains devoid of snow caps do not have tundra vegetation. Therefore, the number of biomes found on a mountain depends upon its latitude and height. Taiga-like forests occur in the temperate areas of the hills but in India such a forest is often of mixed nature having both conifers (*Pinus*, *Cedrus*, *Abies*, *Taxus*, *Picea*) and broad leaved trees (*Quercus*, *Betula*, *Acer*, *Rhododendron*, *Ulmus*, *Aesculus*).

Alpine tundra is the highest altitudinal biome which occurs near the top of very high mountains having permanent snow, e.g., Himalayas. It is a treeless region and lies above the timber-line. Trees of lower region become tiny shrubs in this area (e.g., *Rhododendron*, *Juniperus*, *Abies*). Other constituents of alpine tundra are lichens, mosses, grasses, herbs and small shrubs like *Artemesia*, *Arenaria*, *Primula* and *Anemone*. The plants usually possess spreading or cushion habit and often grow in protected areas. Common animals include mountain goat, yak, wolves, snow leopard, snow bear, rabbit, willow grouse and some migratory birds. Alpine tundra differs from arctic tundra in being slopy, well drained with little peat or bog, more herbaceous flowering plants and dwarfed trees.

Environmental Factors

The constituents of environment which directly or indirectly influence the form and functioning of organisms in any specific way are known as **environmental** or **ecological factors**. They are of two types—abiotic and biotic. The abiotic factors affect the structure, life history, physiology and behaviour of organisms. The biotic factors mostly influence growth and reproduction.

Major Abiotic Factors

Abiotic factors are nonliving factors, substances and conditions of the environment which influence survival, form function, behaviour and reproduction of organisms. There are

many abiotic factors. Out of them the four major abiotic factors are temperature, water, light and soil.

1. Temperature

Temperature or degree of hotness and coldness is the most relevant environmental factor. The average temperature varies seasonally. It ranges from subzero levels in polar areas and high altitudes to more than 50°C in tropical deserts in summer. There are however, unique habitats such as thermal springs and deep-sea hydrothermal vents where average temperatures exceeds 100°C . Not only the physiological functions but also the geographical distribution of many plants and animals is governed by temperature. Mango trees do not and cannot grow in temperate countries like Canada and Germany, snow leopards are not found in tropical forests of Kerala and tuna fish are rarely caught beyond tropical latitudes in the ocean. Temperature has a direct effect on the working of enzymes. Through enzymes, it influences basal metabolism, activity and other physiological functions of the organism.

Atmospheric temperature of a place depends upon its latitude, altitude, topography, slope aspect, season, vegetation and humidity. Temperature gradient over earth's surface or **lapse rate** is $6.4 - 6.5^{\circ}\text{C}$ per 10° latitude or 1000m altitude. There is, therefore, a lowering of mean temperature from equator to poles – tropical, subtropical, temperate and arctic. Organisms living in these zones are respectively called **megatherms**, **mesotherms**, **microtherms** and **hekistotherms**.

Depending upon their ability to tolerate variations in surrounding temperature, organisms are of two types, eurythermal and stenothermal. **Eurythermal organisms** are those organisms which can tolerate a wide range of temperature variations, e.g., most mammals and birds, *Artemesia tridentata* (plant of family asteraceae). **Stenothermal organisms** are those organisms which live within narrow range of temperature because of their requirement of nearly constant temperature throughout the year, e.g., Polar Bear, lizards, amphibians, plants, *Abies*, *Picea* (both cold temperate areas), coconut (warm tropical areas). Plants are **ectothermic**, so are a large number of animals. Their body temperature varies with temperature of the environment. Such ectothermal animals are also called **poikilothermal** or **cold blooded animals**. Birds and mammals are **endothermic**. They keep their body temperature constant despite changes in environmental temperature. Endothermic animals are also called **homoiothermal** or **warm blooded animals**.

Plants belonging to both hot and cold areas possess **adaptations** to reduce transpiration and retain water, e.g., tannins, hair, thick covering, mucilage, high solute content, thick leaves. Animals of cold areas possess thick coat of hair, scales, feathers and subcutaneous fat. In warm blooded animals, including humans, pigmentation is little in colder areas, yellow brown to red in arid climates and black in humid hot areas (**Gloger's rule**). Warm blooded animals (birds, mammals) of colder areas are of larger size as compared to those of warmer areas (**Bergmann's rule**). Extremities of mammals (ears, snout, tail, legs) of colder areas are shorter than those of warmer regions (**Allen's rule**). Birds have narrow wings in cold areas as compared to those of warmer areas (**Ransch's rule**). Fish of colder waters tend to have more vertebrae (**Jordan's rule**).

Effects of Temperature. These are as follows :

(i) **Growth.** Rate of growth increases with the increase in temperature upto an optimum beyond which it begins to decline. Oyster, *Ostracea virginia*, has a length of 1.5 mm at 10°C and 10.3 mm at temperature of 20°C . Eggs of Mackerel take 207 hours to hatch at 10°C and 5 hours to hatch 21°C .

(ii) **Metabolism.** It being enzymes' controlled, is influenced by temperature as depicted by Vont Hoff's law. Chirping of Crickets is louder in summer than at other times. In plants respiration is more affected than photosynthesis.

(iii) **Reproduction.** Maturation of gonads and formation of gametes are controlled by temperature. In grass hopper, increase in temperature from 22°C to 32°C increases egg laying by 20–30 times. Similar is the case with other animals, e.g., Blowfly. Beyond the optimum, fecundity declines.

(iv) **Sex Ratio.** *Daphnia* produces only females at normal temperature. It produces both males and females at higher temperature. Similar rise in male population occurs in *Xenopsylla*.

(v) **Distribution.** Organisms are adapted to live at particular temperatures, e.g., Ice Fish in cold water and Corals in warm waters.

(vi) **Colouration.** Animals have a darker skin in warm and humid areas and lighter skin in arid cool areas (Gloger's rule).

(vii) **Behaviour.** Ticks and certain snakes (e.g., Pit Viper) locate their warm blooded preys by body heat emitted by the latter.

(viii) **Morphology.** In colder areas, the animal size generally increases while the extremities decrease.

A rise in global temperature is likely to prove disastrous for vegetation as plants are mostly stenothermal. The current residents of temperate areas will die down. The tropical plants will not be able to occupy that area because the seasonal fluctuations of temperature will not be conducive for their growth.

Thermoperiodicity. Regular change in temperature that occurs at specific intervals of time is called **thermoperiodicity**. It is of two types (i) **Diurnal Thermoperiodicity.** Temperature is higher during the day and cooler during night. High day temperature favours photosynthesis while lower night temperature stimulates growth and storage in plants. Diurnal periodicity promotes seed germination in many plants. It determines the period of animal activity. For example, desert animals live in burrows, during the hot daytime. They come out in the evening, morning or night. (ii) **Seasonal Periodicity.** Different temperatures prevail in different seasons of the year. They favour different aspects of plant and animal life or phenology. For example, in Tulip, bulbs sprout at $8^{\circ}\text{--}9^{\circ}\text{C}$ (early spring), stem grows at 13°C (mid spring), leaf and flower formation takes place at $20^{\circ}\text{--}30^{\circ}\text{C}$ (late spring or early summer). In Wheat, leaf growth requires a temperature of $10^{\circ}\text{--}25^{\circ}\text{C}$ found in early winter while stem growth is favoured at 30°C found in early spring of wheat growing areas. Apple requires a temperature below 7°C for a period of 800 hrs before flowering and fruiting can occur. Low temperature is required for germination of some seeds, sprouting of bulbs, buds and flowering. Seasonal thermoperiodicity, therefore, controls flowering, fruiting, fruit dispersal, leaf shedding, leaf bearing, seed germination, etc. of plants. It also determines growth, reproduction, development, colouration and morphology of animals. *Daphnia* develops a helmet in spring which grows in summer and disappears in winter. Both low and high temperature cause stress in organisms which is overcome by particular adaptations.

Thermoregulation and Homeostasis. In plants and ectothermal (poikilothermal, cold blooded) animals, the body temperature changes according to temperature of the environment. When the external temperature is lower, some ectothermal animals become extra-active to raise body temperature, e.g., frog, snake. However, very low temperature can kill such animals due to inactivation of enzymes. Therefore, the animals undergo **hibernation**.

In hibernation the animals seek a warm shelter (e.g., burrow, cave, mud, hollow trunk) and remain there listless consuming stored food. Respiration rate is low. In hot weather, cold blooded animals seek shady moist areas where temperature is comparatively low. Some ectothermal animals of hot areas are nocturnal. Other adaptations are formation of winter eggs, cysts and spores. Leaf fall and bud dormancy is common in sensitive plants.

Warm blooded animals, endotherms or homeotherms, maintain a fixed body temperature despite changes in the external environment. Optimum temperature for maximum efficiency of enzymes is about 37°C. Therefore, maintaining a body temperature near it, helps the endothermal animals to have a metabolic advantage. They remain active throughout. **Homeostasis** (=homeostasis) is the phenomenon of maintaining a constant internal environment despite changes in external environment. Endothermal animals show temperature homeostasis. This is done by (a) Retaining **heat** produced by metabolic reactions. (b) Having an **insulating coat** in the form of thick skin, scales, hairs, feathers and subcutaneous fat. (c) Changing **cutaneous circulation**, constricting superficial blood vessels in cold and dilating them in hot weather. (d) **Migration** to warmer areas in winter and cooler areas in summer.

2. Water

Next to temperature, water is the most important factor which influences the life of organisms. Life originated in water. Even now life is unsustainable without water. The productivity and distribution of land plants are dependent upon availability of water. Rain or precipitation is the source of water over land. Therefore, it determines the vegetation of an area.

Annual Rainfall and Vegetation Type. (i) *Evergreen Tropical Forests*. 250-400cm (ii) *Tropical Deciduous Forests*. 100-200 cm. (iii) *Taiga*. 100-250 cm. (iv) *Temperate Deciduous Forests*. 75-150 cm. (v) *Chaparral* 50-75 cm (in winter). (vi) *Grassland and Savannah*. 25-75 cm. (vii) *Desert*. Less than 25 cm.

Terrestrial Plants and Water Availability. On the basis of moisture availability in the habitat, terrestrial plants are of three types — hygrophytes, mesophytes and xerophytes. **Hygrophytes** are plants of wet areas with soft stems of moderate height, large thin leaves with hydathodes for excreting excess water in guttation, e.g., *Ranunculus scleratus*, *Apluda*, *Rumex dentatus*. **Mesophytes** are plants of moist habitats with luxuriant vegetative growth. Spines and thorns are absent. Most crop plants, vegetable and fruit plants are mesophytes. **Xerophytes** are plants of dry habitats which are faced with the problem of more water loss through transpiration than is the water available from soil, e.g., *Acacia*, *Tamarix*, *Casuarina* etc.

Terrestrial Animals and Water Availability. Terrestrial animals obtain their requirement of water from two sources, food and water bodies (e.g., ponds, pools, lakes, rivers, springs, etc.). In arid areas, water resources are lacking. Animals of these areas have to depend upon food as the major source of water. Some of these animals eat only seeds, e.g. Kangaroo Rat. Such desert animals conserve water by a variety of methods. One of them is to produce nearly solid faeces and excrete soild urine.

Aquatic Habitats. Water is abundant in aquatic habitats. Plants of aquatic habitats are called **hydrophytes**. Hydrophytes possess **aerenchyma** or air storing parenchyma to support themselves in water. Clarity of water, salt content, depth and water waves or speed determine the growth and distribution of plants and animals. In rivers and streams, animals obtain most of their food from organic materials coming from outside the water. In ponds and lakes producers grow in sufficient strength. Organisms found in fresh water have a

problem of excess internal water because of endosmosis. Organisms found in ocean or saltish water have a problem of low internal water content due to exosmosis. Some have problem of excreting excess salts obtained from outside. In oceans at a depth of more than 200 m, producers do not occur. Only consumers are found there. Deep sea animals do not possess air sacs. Many of them are luminescent.

Water currents restrict distribution of organisms in streams and intertidal areas of oceans. In streams only attached plants grow. They have dissected or ribbon shaped leaves. Animals found here are either strong swimmers, have attaching organs or live under stones, in burrows, crevices etc. Similarly in intertidal area of ocean attached plants (*Fucus*, *Laminaria*), sessile animals (Sea anemone and limpets), burrowing animals (e.g., *Nereis*, tube worms) or very strong swimmers are met with.

We might think that organisms living in oceans, lakes and rivers should not face any water-related problems, but it is not true. For aquatic organisms the quality (chemical composition, pH) of water becomes important. The salt concentration (measured as salinity in parts per thousand), is less than 5 per thousand parts in inland waters, 30–35 per thousand parts in the sea and more than 100 per thousand parts in some hypersaline lagoons. Some organisms are tolerant of a wide range of salinities (**euryhaline**, e.g., Salmon) but others are restricted to a narrow range (**stenohaline**, e.g., Shark). Many freshwater animals can not live for long in sea water and *vice versa* because of the osmotic problems they would face.

3. Light

Light is the visible part of electromagnetic spectrum (390–740nm). Solar radiations have a wavelength of 300–2600 nm. Photosynthetically active radiations (PAR) have a range of 400–700 nm. Radiations below the visible light are ultra violet (UV) radiations while those above the visible light are infra-red or heat waves. Amount of light and its intensity vary with latitude and season. Light intensity, light duration and light quality influence a number of life processes of organisms.

(i) **Photosynthesis.** Light is essential for photosynthesis. The amount of photosynthesis depends upon the quality, intensity and duration of light. Photosynthetic yield is maximum at equator and tropical areas. Yield is 50% at 50° latitude.

(ii) **Growth.** It is favoured by increased availability of food, moderate light intensity and red light. UV radiations favour rosette habit in plants. Blue light favours moderate but normal growth. High light intensity reduces growth but increases development of mechanical tissues. Leaves are smaller but thicker. Shoots have smaller internodes. Flowering is increased. Differentiation of various tissues and organs in response to light is called **photomorphogenesis**. Aphids develop wings in response to alternate light and darkness.

(iii) **Transpiration.** Stomata generally open in light and close in darkness. Because of it light promotes transpiration. Transpiration is further enhanced by heating effect of light.

(iv) **Germination.** A number of seeds are sensitive to light. They are called **photoblastic seeds**. Positively photoblastic seeds germinate only in the presence of light, e.g., *Viscum*, *Lactuca*, *Rumex*. Negatively photoblastic seeds do not germinate in presence of light, e.g., Onion, Tomato, Phlox.

(v) **Pigmentation.** Animals develop dark colour in dim light and light colour in bright light. In humans prolonged exposure to light causes **tanning** or darkening of skin. Some animals show seasonal colour changes. Snow Hare becomes completely white with the approach of autumn/winter. Many plants develop brown leaf colouration during autumn. They are light green in moderate light. In strong light leaves develop yellow and red tints.

(vi) **Movements.** Small photosynthetic organisms show positive phototaxis in moderate light, e.g., *Chlamydomonas*, *Euglena*, *Volvox*. Plant shoots bend towards the source of light. It is positive **phototropism**. Flowers of some plants open or close in response to light and darkness. The phenomenon is called **photonasty**. **Nyctinasty** is folding of leaves in response to darkness. *Planaria* and Earthworm generally show negative phototaxis.

(vii) **Daily Rhythm in Animals.** Most animals are active during a particular period of the day. (i) **Diurnal** (active during the daytime), e.g., butterflies, most birds, most mammals. (ii) **Nocturnal** (active during night), e.g., Rat, Owl, Cockroach. (iii) **Auroral** (active at dawn or early morning), e.g., *Bubalus*. (iv) **Vesperal** (active at the time of dusk or sunset), e.g., Rabbit (v) **Crepuscular** (active during dawn and dusk).

(viii) **Photoperiodism.** It is response of organism to number and duration of day lengths. Organisms show three types of response to light duration – short day, long day and day neutral. **Phenology** or the timing of seasonal activities of organisms (e.g., flowering, migration) is usually controlled by photoperiodism. (i) **Bird Migration.** Birds of colder areas of northern hemisphere begin their southward migration as the day lengths begin to shorten. Reverse journey is undertaken with the increase in day length. (ii) **Leaf Fall and Dormancy.** The two phenomena occur in temperate and subtropical areas in response to shortening daylength. (iii) **Hibernation.** In temperate and subtropical areas, cold blooded or ectothermic animals undertake hibernation as the day length begins to shorten. (iv) **Flowering.** Most plants flower at a particular season in response to a particular photoperiod, e.g., spring, summer, autumn or winter. (v) **Vegetative Growth.** In certain plants growth of vegetative storage organs is favoured by short day conditions (e.g., Potato, Dahlia, Artichoke, Radish) while in others it is favoured by long day conditions (e.g., bulbs of Onion and Garlic). (vi) **Animal Breeding.** Turkeys, Ferrets and Starling breed in response to lengthening of days while Goat, Sheep and Deer breed in response to shortening of days. Rabbits and Guinea Pigs are day neutral.

Light Zones in Aquatic Habitats. There is a light zonation in deep lakes and oceans. (i) **Littoral Zone.** It is shallow coastal region. Light is able to pass through shallow water and reach the bottom. Therefore, producers occur throughout from surface to bottom. (ii) **Limnetic Zone.** It is open water zone where water is very deep. Amount of oxygen and light decreases with depth.

Limnetic zone has three parts — photic, aphotic and benthic.

(a) **Photic Zone.** It is upper part of limnetic zone to which light can penetrate. Depth is upto 200m. The upper part of photic zone, called **euphotic zone**, receives light more than the compensation point. Its depth is 20-80m. The lower part of the photic zone, called **disphotic zone** (twilight zone), receives light at or below the compensation point. Blue light being made of short wave radiations can reach the deepest. Red light has poor penetrability. In sea the green algae remain near the surface, brown algae in intermediate depths while red algae flourish the deepest in the photic zone.

(b) **Aphotic/Profundal Zone.** It is zone of deep water below the photic zone and above the bottom to which light does not penetrate. The zone is, therefore, in perpetual darkness. Producers do not occur in this part. Instead only consumers are found. (iv) **Benthic Zone.** It is the bottom zone. In deep lakes and seas, the bottom is also in perpetual darkness but in shallow waters, light does penetrate.

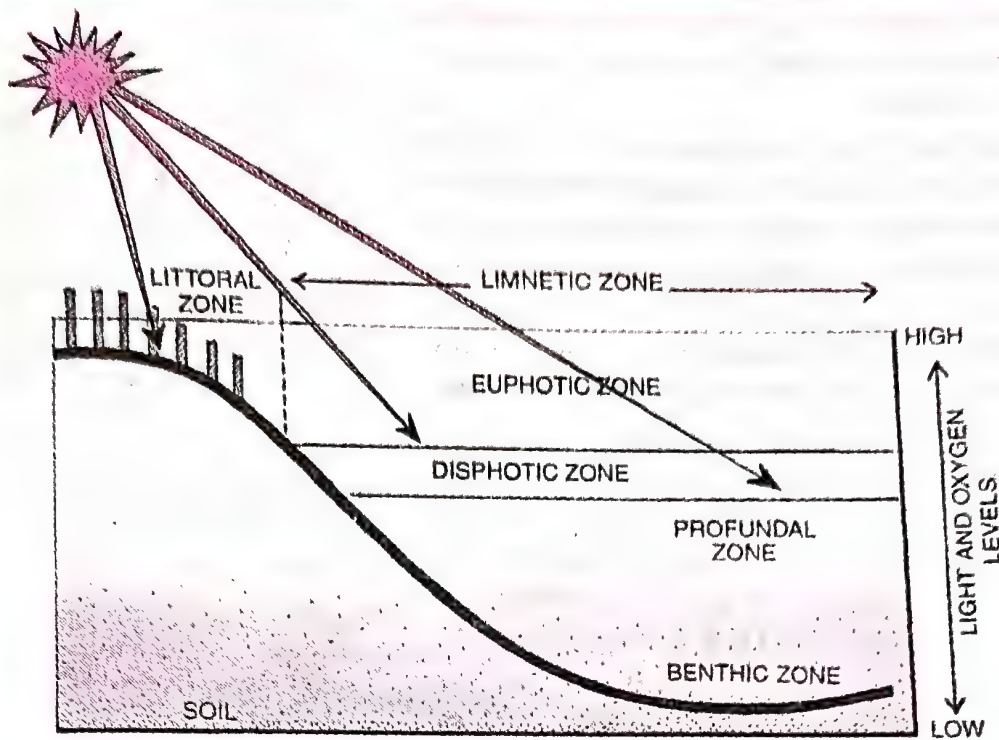


Fig. 13.8. Zones in deep lake and ocean.

4. Soil.

It is the upper weathered humus containing part of earth's surface which sustains terrestrial plant life. **Weathering** or breaking of rocks into fine powder can occur due to atmospheric changes, mechanical forces (mechanical weathering), chemical changes (chemical weathering) and biological breakdown (biological weathering). The weathered mineral matter is changed to soil by the process of **pedogenesis** (pedology is science of soil) which involves **humification** (formation of humus), **eluviation** (washing down or leaching) and **illuviation** (deposition in lower layers). **Residual soils** develop *in situ*. **Transported soils** are brought from other places through gravity (**colluvial**), running water (deposited at flood plains and called **alluvial**), wind (**aeolian** = aeolian) and glacier (**glacial soil**). The science dealing with study of soil is called **edaphology**, **paedology** or **pedology**.

Soil Profile (Fig. 13.9). The appearance of different layers superposed one above the other in a vertical section of the soil from surface downward to the parent rock is called **soil profile**. Soil layers running roughly parallel to the surface which have distinctive structure and properties different from those of adjacent ones are called **soil horizons**. Each horizon may be further divisible into subhorizons. A soil contains maximum of 3 horizons of its own in addition to a layer of surface litter. The three horizons of the soil are called A, B and C. The surface litter layer is called O-horizon. Only A and B horizons represent true soil or **solum** because they have weathered products of the parent rock.

(i) **O-Horizon**. It is a surface layer of organic matter which lies above the true soil. It has two sub-horizons, A_{00} (O_1) and A_0 (O_2). A_{00} is the upper sub-horizon which contains freshly deposited organic debris of fallen leaves, twigs, bark, animal remains and animal excretions. A_0 is sub-horizon below the A_{00} and immediately above the top soil. It contains organic matter in various stages of decomposition. Decomposition ultimately produces a dark

brown or black coloured amorphous substance called **humus**. Humus and its components pass into the top soil along with percolating rain water. It is reservoir of plant nutrients.

(ii) **A-Horizon**. It is the uppermost horizon of the soil which is also called the **topsoil**. This horizon contains mineral matter mixed with humus. It is, therefore, light weight, spongy and dark in colour. Thickness of A-horizon as well as its mineral content determines the fertility of the soil. A-horizon is a few cm to 3 m in thickness. Roots of most of the plants remain restricted to A-horizon. The horizon is rich in microorganisms. Therefore, the layer has very high biological activity. Even burrows of small animals occur only in A-horizon, *e.g.*, Mice. Being close to the surface, A-horizon also has good availability of air and water. A-horizon is divisible into three sub-layers or subhorizons— A_1 , A_2 and A_3 . A_1 is the uppermost sublayer which is dark in colour, rich in organic matter and inorganic nutrients. A_2 is second sub-horizon which is also the area of maximum leaching or **eluviation**. As a result it is slightly lighter in colour and slightly deficient in inorganic nutrients. A_3 is transitional subhorizon between A and B horizons. The subhorizon is lighter in colour, compact in nature with good hydration but poor in microorganisms as well as aeration. Highly fertile soils have dark brown or blackish colour in the A-horizon. Red, bright yellow or grey top soils have lesser amount of organic matter. They are also deficient in nitrogen and other plant nutrients.

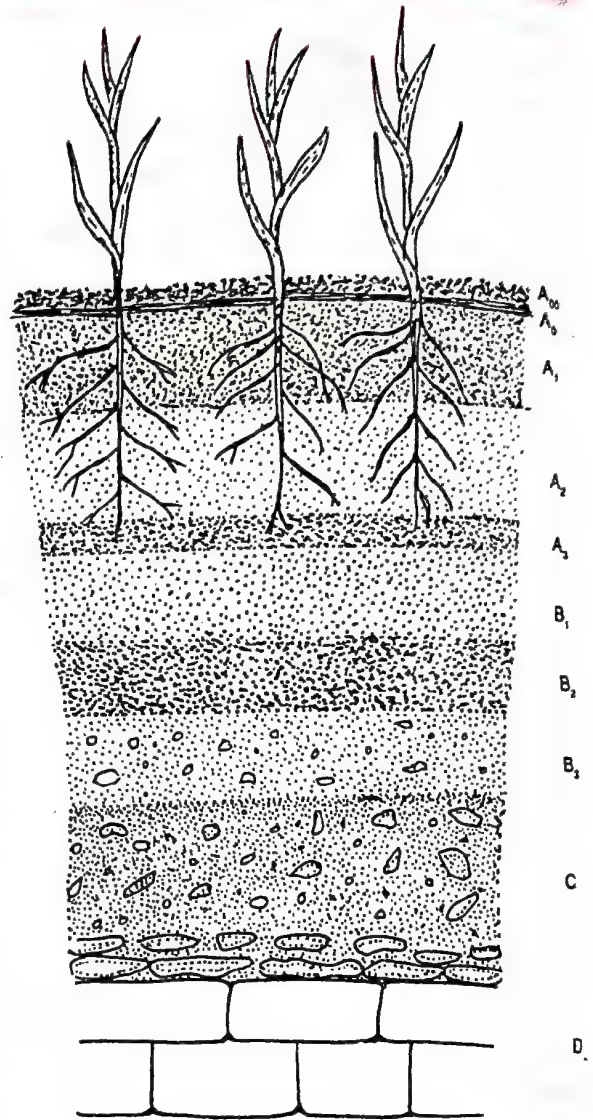


Fig. 13.9. An ideal soil profile.

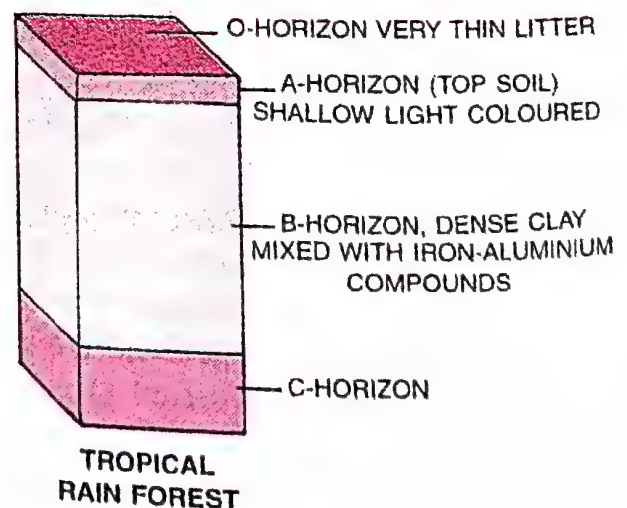
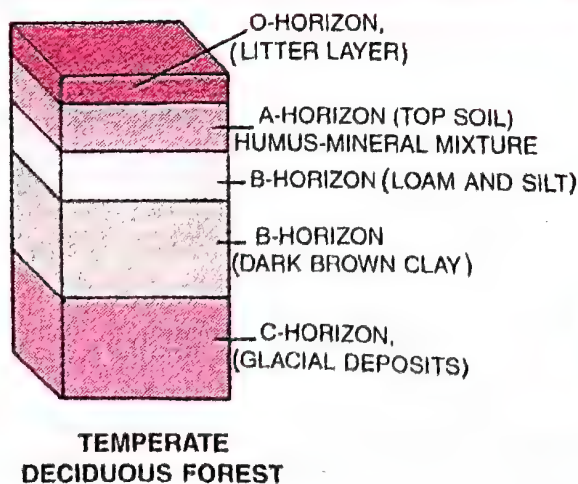


Fig. 13.10. Comparison of soil profiles of temperate deciduous and tropical rain forest. A, Temperate Deciduous Forest. B, Tropical Rain Forest.

(iii) **B-Horizon.** It is also called **subsoil**. The thickness can be upto 1.0 m. The subsoil receives various materials reached from topsoil. It is thus the area of deposit of materials or **illuviation**. The horizon is poor in aeration and biological activity. It is rich in plant nutrients including humus but illuviation also causes formation of compact and hard sublayers. B-horizon is differentiated into three sub-horizons— B_1 , B_2 and B_3 . B_1 is dark coloured, humified and somewhat compact subhorizon which receives deposits of organic matter or humus from above. B_2 contains deposits of inorganic nutrients, clay and heavy metals. It is often hard. B_3 is transitional subhorizon between B and C horizons. It contains small rock fragments stained with materials leaching from above.

(iv) **C-Horizon.** It contains irregular rock fragments. Biological activity is nil. The horizon is saturated with moisture and represents the water table.

(v) Unbroken and unweathered parent bed rock lies below C-horizon.

Soil profile shows changes in different biomes (e.g., grassland, forest, desert) as to colour, mineral, organic matter and depth. There is little organic matter in top soil in desert soils. Subsoil has little depositions. It is made of sand, some clay, minerals and salts. Soil of grasslands receives a lot of organic matter each year. Roots penetrate deep, form dense sod that holds a lot of moisture and prevents erosion. In temperate forests the top horizon is rich in humus and inorganic soil components. B_1 has loam and silt while B_2 is dark brown with clay deposition. In tropical rain forests the soil is shallow and nutrient poor due to dense clay subsoil mixed with iron-aluminium compounds, high temperature and heavy rainfall.

Soil Types. A soil having a soil profile is called **zonal soil**. A soil devoid of horizons is called **azonal soil**. Azonal soil is either **immature soil** (e.g., desert soil, slope soil) or **alluvial soil** (deposited by running water). Zonal soil is also called **residual soil** because it is formed *in situ* from the parent rock. Four common types of soils found in India are red soils, black soils, alluvial soils and terai soils. **Red soils** are acidic soils which are rich in iron and aluminium but are deficient in lime, magnesium, phosphorus and potassium. These soils are formed through a process called **laterisation** in which silica dissolves and leaches downwardly but iron and aluminium remain on the top soil. Red soils are, therefore, called **laterite soils**. **Black soils** are dark brown or black coloured soils having good quantity of organic matter. The soil contains clay or hydrated silicates of iron and aluminium. They are locally called **regurs** or **black cotton soils**. The soils are also called **A-C soils** because B-horizon is generally non-differentiated. **Alluvial soils** are transported soils which have been formed by siltation of rivers and sea. **Terai soils** occur over the foot hills. They are mostly made up of rock particles slipping along the slope by force of gravity and rain wash. Such soils are also called **colluvial soils**. Well drained colluvial soils are highly fertile. The dry terai soils are called **Babar soils**.

Soil Composition. Soil has five components— mineral matter, organic matter, soil organisms, soil moisture and soil air. The proportions of different components are as follows:

Mineral matter	—	40%
Organic matter	—	10%
Soil moisture	—	25%
Soil atmosphere	—	25%
Soil organisms	—	Variable

Mineral Matter. It consists of small irregular particles formed by weathering of parent rock. They enclose small spaces for holding and circulation of water and air. There are four types of mineral particles.

Gravel (Fine pebbles)	—	1–2 mm
Coarse Sand (Quartz or SiO_2)	—	0.2–2.0 mm
Fine Sand (SiO_2)	—	0.02–0.2 mm
Silt (Very fine quartz grains)	—	0.002–0.02 mm
Clay (Hydrated silicates of aluminium)	—	Less than 0.002 mm

Sand particles are chemically sterile. They enclose larger non-capillary pores which can hold air but not water. Clay particles are chemically active. They enclose finer capillary spaces which can hold water but not air. Silt has intermediate character, *i.e.*, moderately active chemically enclosing spaces for both water and air.

Soil Texture. It is a physical structure of the soil which is due to size, proportion and arrangement of its constituents. Three main types of soil texture are sandy, clay and loam. They are based on the proportion of three types of mineral particles (sand, clay and silt). (a) **Sandy Soils.** The soils contain about 80% or more of sand, the remaining being silt and clay. Sandy soils are porous and loose. Water holding capacity is poor. Rain or irrigation water quickly percolates downwardly. Chemical nutrition is little. There is little resistance for growth of underground parts. Addition of manure helps in retaining water as well as providing mineral nutrients. Manured sandy soils are used for growing plants having underground parts like Groundnut. (b) **Clay Soils.** They are soils having 40–50% of clay, the rest being silt. Sand is little. Clay soils have abundant capillary pores. Therefore, water holding capacity is high. Inorganic nutrients are available in good quantity. However, aeration is poor. The soils are compact. Root penetration is difficult. So is ploughing. (c) **Loam soils.** The soils contain 20% clay, 40% sand and 40% silt. They have good mineral nutrition, aeration and hydration. Therefore, loam soils are the best for plant growth.

Organic Matter. It is derived from **litter** or organic remains strewn over soil surface, like fallen leaves, twigs, excretions of organisms and their dead bodies. Undisturbed litter forms a sort of mat over the surface of soil. It undergoes slow decomposition to produce humus. **Humus** is dark brown amorphous gummy substance formed by partial decomposition of plant and animal matter that constitutes the organic component of soil. Humus is only slightly soluble in water and, therefore, largely stays in the top soil. Only a small quantity seeps downwards. The same coats soil particles, binds them together and forms soil aggregates.

Humus is formed from organic remains through the activity of decomposer microorganisms. Process of formation of humus from raw organic remains is called **humification**. It is slow because many constituents of organic matter are slow to degrade, *e.g.*, lignin, cellulose. Humus contains partially decomposed products of cellulose, hemicellulose and lignin. With time, they are broken down completely. Therefore, in order to maintain organic component of soil, new humus has to be formed regularly. Manure is added to crop fields for augmenting humus.

- Importance.** (i) Litter insulates the soil from excessive heating and cooling.
 (ii) It functions as a sponge and does not cause rain water to run-off.
 (iii) Litter protects the soil from direct action of wind and rain drops.
 (iv) Gums present in humus bind soil particles into aggregates or crumbs. Soil aggregates are soft and spongy. They increase water holding capacity of top soil.
 (v) Humus increases aeration of soil and allows easy penetration of root hairs into soil spaces.

- (vi) It contains organic colloids that hold cations over their surface for absorption by plant roots.
- (vii) Humus possesses acids for solubilisation of soil minerals.
- (viii) It has some growth promoting chemicals.
- (ix) As humus decays, the inorganic nutrients trapped in organic matter, are released in the soil.

Soil Organisms. A number of organisms live inside soil. They include bacteria, actinomycetes, fungi, algae, parts of higher plants, protozoa, rotifers, nematodes, insects, earthworms, molluscs and burrowing vertebrates. They are the **living components** of the soil. Ecologists differentiate the various soil organisms into microflora, microfauna, macroflora and macrofauna. The important functions of soil organisms are as follows :

(1) Decomposition of organic matter and release of inorganic nutrients for recycling. Organic matter is first acted upon by detritivorous soil fauna (e.g., termites, carpenter ants, crabs, insect larvae, earthworms, millipedes, molluscs). The fragmented matter is then acted upon by microorganisms, e.g., bacteria, actinomycetes, fungi. This releases inorganic nutrients. The phenomenon is called **mineralisation**. Some microorganisms also change the released raw materials into useful form e.g., sulphur bacteria ($\text{H}_2\text{S} \rightarrow \text{SO}_4$), nitrifying bacteria ($\text{NH}_3 \rightarrow \text{NO}_3$). (2) A number of free living bacteria and blue green algae take up gaseous nitrogen and change the same into organic form of nitrogen. The process is called the **nitrogen fixation**, e.g., *Azotobacter*, *Nostoc*, *Anabaena*. (3) Microorganisms convert organic matter into **humus**. Humus is highly useful for maintaining crumb structure, sponginess, aeration and hydration of soils. It also provides growth stimulants to plants. (4) Earthworms and insects help in soil mixing, maintenance of soil porosity and soil fertility. (5) Decaying roots of plants and burrows of small animals, produce passages in the soil for flow of water and air. (6) A number of diseases are caused by soil borne bacteria, fungi and nematodes. (7) Burrows of large animals are a source of loss of soil moisture. The soil near the burrows becomes loose and infertile.

Soil Porosity. The percentage of soil volume occupied by pore spaces is called soil porosity. It is 30% in sandy soil, 40% in loam soil, 50% in clay soil and upto 60% in well manured loam soil. Soil pores are of two types, **micropores** and **macropores**. Micropores have a diameter of upto 20 μm while macropores possess a pore diameter of more than 20 μm . Macropores hold air. Larger sized macropores (50 μm and above) take part in percolation of water in the soil. Micropores hold water by capillarity.

Soil Air. It is essential for roots and soil organisms. In a good soil 25% of total volume of the soil is filled with air. Composition of soil air depends upon ventilation or number of macropores connected with soil surface. Soil air is generally richer in carbon dioxide. Oxygen content is less than normal. However, low oxygen content is harmful. 5–10% of oxygen is essential for roots. Below this they get killed. Water absorption occurs in root only when oxygen concentration is more than 10%. Reduced oxygen content kills aerobic organisms. As a result, mineralisation of decaying organic matter is impaired. Environment of the root becomes reducing. It produces a number of toxic compounds. Heavy metals and silica solubilise resulting in toxic effects.

Soil pH. It determines the type of soil microorganisms, solubility of different minerals and type of plants which grow. In alkaline soils (pH above 7) there is reduced availability of Zn, Mn and iron. In acidic soils there is abundance of iron, Mn and Al but deficiency of Ca, Mg and K. Availability of minerals is optimum in neutral soils. Plants grow best in neutral and

slightly acidic soils. Slight acidity of soil favours forest formation while slight alkalinity promotes formation of grasslands. Different crop plants require different pH. Certain soils possess excess of salts especially those of Na and Mg. They are called **saline soils**. Salinity increases with excessive irrigation. Saline soils are virtually barren because very few plants can grow in such soils. Another category of infertile soil is alkali soil. Both the soils can be made fertile by digging trenches, addition of gypsum and other acidic chemicals.

Soil Moisture or Soil Water (Fig. 13.11). It is one of the most important ecological factor in the distribution of biota. Soil moisture is derived from rain. In crop fields irrigation is another source of soil water. A part of rain or irrigation water flows over the soil as **run-away water** and a part percolates downwardly to water table. The latter is called **gravitational water**. Water held in soil is of four types —

- Hygroscopic Water.** It is the water adsorbed or imbibed by the soil colloids. It is not available to the plants as the water is held very firmly by the soil particles.
- Water Vapours.** They occur in the soil atmosphere to make the latter saturated. Though not available to the plants, a component of this water condenses during night so as to wet the areas dried by evaporation.
- Combined Water.** The water occurs bound up in chemicals and is thus unavailable.
- Capillary Water.** It is water present inside micropores. It is the water available to plant roots. The content of capillary water depends upon soil texture.

The maximum amount of water a soil can hold after the stoppage of gravitational flow is known as **field capacity** (Fig. 13.12). For loam soils, the field capacity is 25–30%. Water potential at field capacity of common

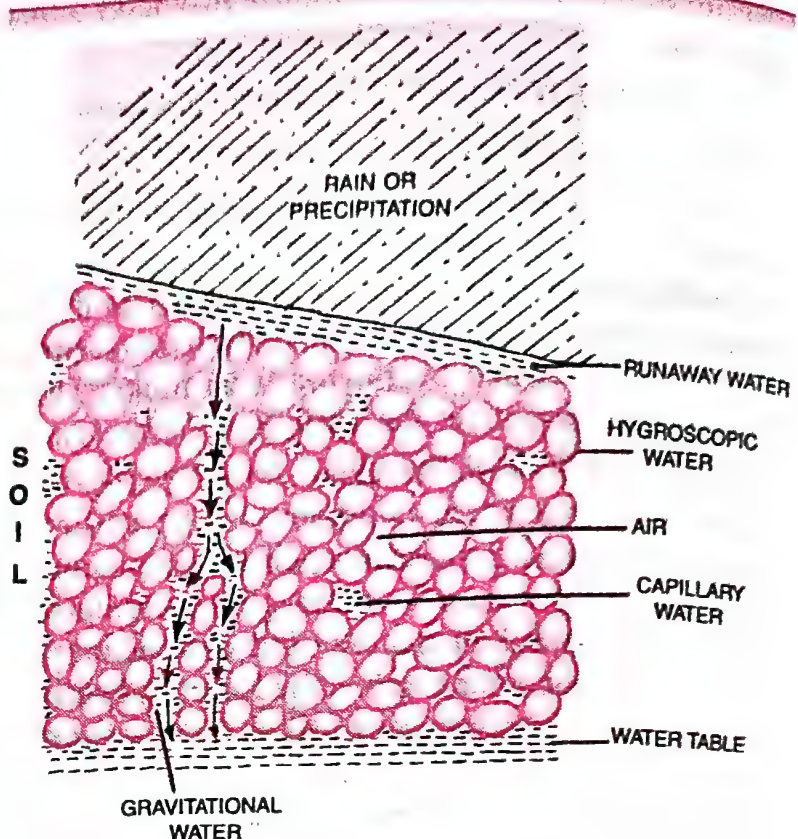


Fig. 13.11. Types of soil water.

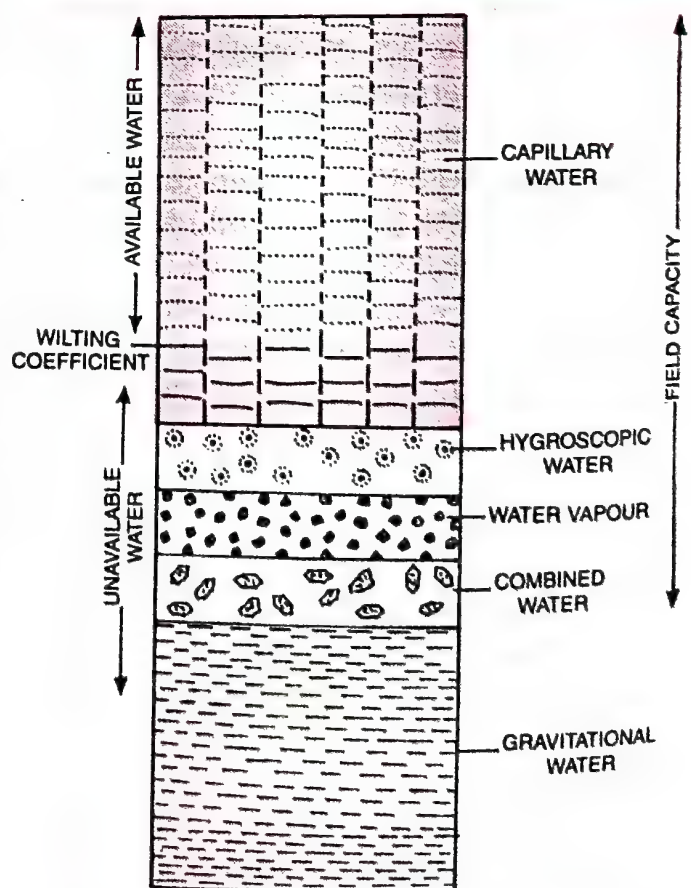


Fig. 13.12. Various fractions of soil water.

soil is -0.01 MPa ($= -0.1 \text{ bar}$). Water added to soil after the achievement of field capacity goes waste. Rather it may cause water logging. A water logged soil cannot support good plant growth due to reduced aeration. If water is not replenished in the soil, evaporation and plant absorption will continuously reduce the content to a stage called **permanent wilting percentage or coefficient** (PWP or PWC). It is that percentage of water per unit of dry soil when the plants growing in it undergo **permanent wilting** (recovery not possible even under 100% humid air). At PWP water is mostly hygroscopic or held over the surface of particles including very narrow micropores of $0.2 \mu\text{m}$ or less. Water potential at permanent wilting (wilting point) is -1.5 MPa ($= -15 \text{ bars}$). Total soil water content or **holard** consists of two parts, **chresard** (water available to plants) and **echard** (water not available to plants, i.e., hygroscopic, combined and vapours).

As per **Schimper's second law**, the local distribution of plants (and hence the occurrence of animals) is determined by soil. In an aquatic habitat, the sediment characteristics determine not only the submerged anchored hydrophytes but also the benthic animals.

Responses to Abiotic Factors

External environment is seldom uniform nor always favourable. There are periods and conditions when it becomes stressful, e.g., low temperature, high temperature, excess water, drought, adverse pH or salt concentration, etc. Ideally during the course of million of years of their existence most species should have evolved a relatively constant internal environment (within the body of the organism). This uniform internal environment would permit all biochemical reactions and physiological functions to proceed with maximal efficiency and, therefore, increase the overall fitness of the species. It may be in the form of optimum temperature and osmotic concentration of the body fluids. Therefore, all organisms should maintain a constant internal environment. The ability of an organism to keep the internal environment constant despite drastic changes in external conditions is called **homeostasis**. An analogy may be mentioned. Suppose a person is able to perform his/her best when the surrounding temperature is 25°C and wishes to maintain it even during very hot or very cold outside. He/she can do it at his work place in the car while travelling and at home by using an air conditioner in summer and a heater in winter. In such conditions his/her performance would be maximum inspite of adverse environment around him. In this case, the person's homeostasis is maintained not through physiological but through artificial or technical means.

Possibilities to Cope with the Adverse Situations

Living organisms cope with stressful conditions by any of the following methods (Fig. 13.13)

1. **Regulate.** Some organisms are able to maintain a constant body temperature and constant osmotic concentration despite changes in the external environment. They are called as regulators ($=$ regulators). Only birds, mammals, very few lower vertebrates and invertebrates belong to the category of **regulators**. They perform homeostasis mostly through thermoregulation and osmoregulation by physiological adjustments and rarely by behavioural changes. Evolutionary biologists believe that the success of mammals is mainly due to their ability to maintain a constant body temperature (**endotherms**) and live comfortably whether they are in Artarctica or in Sahara desert.

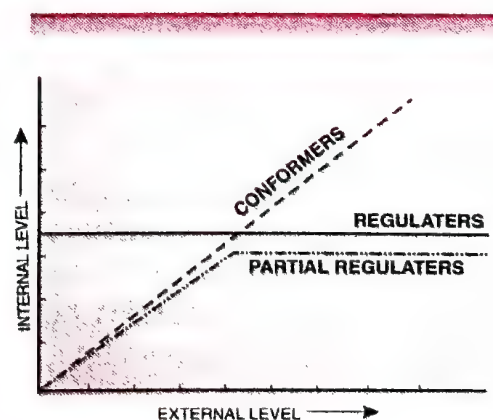


Fig. 13.13 . Diagrammatic representation of ways of organismic response.

In most mammals, the mechanisms to regulate their body temperature are similar to those of human beings. We keep our body temperature constant at about $\sim 37^{\circ}\text{C}$. At many places the external temperature rises to 45°C in summer and dips to near zero in winter. We begin to sweat profusely when external temperature rises above 37°C . Cooling of body occurs as the sweat evaporates, a mechanism similar to what happens with a desert cooler. When the external temperature is low, our body will inadvertently start shivering. It is an exercise that raises body temperature. Behavioural changes for thermoregulation are observed in some reptiles — basking in the sun or excessive activity during winter, staying in cool moist burrows during summer days. However, plants being fixed, cannot have behavioural changes. They can cool their body in summer through transpiration if water is available.

2. **Conform.** About 99 percent of animals and nearly all plants do not have a mechanism to maintain a constant internal body environment. Their body temperature changes with the surrounding temperature (**ectotherms**). In aquatic animals, the osmotic concentration of body fluids changes according to the osmotic concentration of the surrounding water, e.g., *Asterias*. These animals and plants in which the osmotic concentration and temperature of body change according to ambient conditions of water are called **conformers**. The efficiency of conformers is reduced under stressful conditions. Therefore, the question arises—why have all the organisms not developed homeostasis when it is extremely beneficial. The reason is that homeostasis especially thermoregulation is energetically expensive. Heat loss or heat gain is directly related to surface area. Small animals (e.g., shrew, humming bird) have large surface area as compared to their volume. In colder environment, they tend to lose heat very fast. They will have to spend more energy in maintaining their body temperature as compared to large sized animals. It is because of this reason small sized animals do not occur in polar regions.

Differences between Regulators and Conformers	
Regulators	Conformers
1. They possess a constant internal environment or homeostasis.	1. Homeostasis is little.
2. They maintain their body temperature.	2. Their body temperature changes according to that of environment.
3. The body fluids have a fixed osmotic concentration.	3. Osmotic concentration of body fluids varies according to that of external medium.
4. They consume large amount of energy.	4. They consume lesser amount of energy.
5. They have a wide range of distribution.	5. They have a narrow range of distribution.
6. Regulators are more active.	6. Conformers are less active.

Considering the huge cost of maintaining a fixed body temperature and osmotic concentration of body fluids, many organisms have not evolved homeostasis. It is similar to a person of moderate means who is unable to afford an air conditioner in summer or a heater in winter. Some species are **partial regulators**. They have the ability to regulate body functions to a limited extent. Beyond that limit they become conformers. Further, it is not essential that regulators of one attribute would be regulators in other attributes as well. All vertebrates, most molluscs and cray fishes are **oxyregulators** but with the exception of birds and mammals, they are **thermoconformers** and **osmoconformers**.

If the unfavourable external conditions remain only for a short time, the organism has two other alternatives being described below.

3. **Migrate.** The organism can migrate temporarily from the unfavourable habitat to more favourable area and return when unfavourable period is over. This strategy is like a person who is moving from Delhi to Shimla for the duration of summer. Many animals, particularly birds, during winter go long-distance migrations to more favourable areas. Every winter the Keoladeo Ghana (Bharatpur) National Park in Rajasthan receives thousands of migratory birds which come from Siberia and other very cold northern regions.

4. **Suspend (Stop for a time).** Various kinds of thick walled spores are formed in bacteria, fungi and lower plants which help them survive under unfavourable conditions. These germinate on return of suitable conditions. In higher plants, seeds and some other vegetative reproductive structures cope with the unfavourable conditions besides helping in dispersal. They germinate to form new plants under favourable moisture and temperature conditions. In animals, the organism, if unable to migrate, might avoid the unfavourable environment by escaping in time. For example, polar bears go into **hibernation** during winter season to escape extreme cold. Some snails and fish undergo **aestivation** to avoid summer-related problems like heat and desiccation. Under favourable conditions many zooplankton in lakes and ponds are known to enter **diapause** i.e., a stage of suspended development.

Infact, diapause is a stage in the development of certain animals, during which developmental growth is suspended during winter when days are short. Diapause is thus influenced by light, e.g., in winter the larvae of **pink cotton bollworm** enter into diapause. It is different from hibernation.

Adaptations

Definition. Adaptation is a quality of the organism (morphological, physiological, behavioural) that enables the organism to survive and reproduce in its habitat. Adaptations allow organisms to live in different types of habitats. They develop due to natural selection of suitable variations appearing in living beings through mutations and recombinations. Adaptations are of two types, phenotypic and genotypic. **Phenotypic adaptations** are favourable changes in morphology and physiology which develop in response to changes in environmental conditions. They disappear when the environmental conditions become normal. The ability of a genetically similar populations to undergo phenotypic changes in response to variations in environment is called **phenotypic plasticity**. The phenotype variants formed in a population due to changes in environment are called **ecophenes** or **ecads**.

Genotypic adaptations are genetic variations which enable a subpopulation to adapt itself to a particular habitat and environment conditions. A species with a long range may have such subpopulations. They are called **ecotypes**. The different ecotypes are interfertile and produce intermediate forms in transition areas.

Plant Adaptations to Light Regime— Sun and Shade Plants. Plants growing in bright light are called **sun plants** or **heliophytes** while plants growing in partial shade or low intensity light are called **shade plants** or **sciophytes**. In a forest, plants get arranged in various strata according to their shade tolerance. The phenomenon is called **stratification**. Sun plants or heliophytes, have shorter and thicker internodes, smaller and thicker leaves, thicker cuticle and epidermal cells and sunken stomata. The leaves are pale green in colour with shining surface or hairy growth. Palisade parenchyma is well developed. Cells are smaller. Intercellular spaces are small. Root system is extensive. There is good amount of flowering and fruiting. In shade plants or sciophytes, the stems are soft, slender with large internodes. Leaves are thin and large sized. They have bright green colour. Leaf cells are large. Cuticle is thin. Stomata are in level with the surface. They are present on both the

surfaces. Palisade parenchyma is less developed. There is more vegetative growth as compared to flowering and fruiting.

Sun plants are adapted to higher temperature optima for photosynthesis and high rates of respiration. Shade plants have low photosynthetic, respiratory and metabolic activities. Perfect shade tolerant plants are ferns and several herbs which grow on forest floor under the canopy of trees and shrubs.

Differences between Sun Plants and Shade Plants	
Sun Plants	Shade Plants
1. The stems are thicker with shorter internodes.	1. The stems are narrower with longer internodes.
2. There is increase in branching.	2. Branches are fewer.
3. Leaves are smaller and thicker.	3. Leaves are larger and thinner.
4. Leaf colour is pale green with tints of other colours.	4. Leaves colour is bright green.
5. Leaf surface is shining or hairy to reduce insulation.	5. Leaf surface is dull. Hair if present are fewer.
6. Leaf cells are smaller with smaller chloroplasts.	6. Leaf cells are larger with larger chloroplasts.
7. Epidermis is thick walled. Cuticle is thick.	7. Epidermis is thin walled. Cuticle is thin.
8. Stomata are generally sunken and are present on lower surface.	8. Stomata occur in level with surface and generally on both the surfaces.
9. Palisade parenchyma is more developed.	9. Palisade parenchyma is less developed.
10. Spongy parenchyma is weakly developed.	10. Spongy parenchyma is well developed.
11. Mechanical tissues are more developed.	11. Mechanical tissues are moderately developed.
12. Osmotic pressure is higher.	12. Osmotic pressure is lower.
13. Light compensation point is higher (100–400 ft candles).	13. Light compensation is lower (25–100 ft candles).
14. There is abundant flowering and fruiting.	14. Flowering and fruiting are less while vegetative growth is more.

Plant Adaptations to Water and Heat—Xerophytes. They are plants of dry habitats where the environment favours higher rate of transpiration than the rate of absorption. Xerophytes are of four types— (i) **Ephemerals** or **Drought Escapers**. The plants live for a brief period during the rains. The rest of the year is passed in the form of seeds, e.g., *Euphorbia prostrata*, *Tribulus terrestris*, *Boerhaavia*. (ii) **Annuals** or **Drought Evaders**. The plants live for a few weeks even after the stoppage of rains. The size remains small. Leaves have thick waxy, hairy coating with or without prickles to reduce transpiration, e.g., *Echinops echinatus*, *Solanum surattense*. (iii) **Succulents** or **Drought Resistant**. The plants have fleshy organs where water and mucilage are stored. Depending upon the organ where succulence occurs, the succulents show **chylocauly** (fleshy stems, e.g., *Opuntia*, *Euphorbia*, *Asparagus*) and **chylophyllly** (fleshy leaves, e.g., *Aloe*, *Agave*), or **chylorhizy** (fleshy roots, e.g., *Asparagus*). Chylocaulous forms generally possess leaf scales or leaf spines. The stems are green and photosynthetic. They are called **phylloclades** (stems of indefinite growth) and **cladodes** (1-2 internode long stems). Stems and leaves of succulents possess very thick cuticle. Stomata are sunken and open during night only. Succulents perform a different type of photosynthesis called **crassulacean acid metabolism** or CAM. (iv) **Non-succulent Perennial Xerophytes** or **Drought Endurers**. They are true xerophytes which actually tolerate drought conditions. They have smaller shoot system. The root system is

very extensive. It may spread along the soil surface in order to absorb every drop of rain as well as dew. In a type of xerophytes called **phreatophytes** the roots are very deep. They reach the water table. Phreatophytes are, generally, used to locate ground water, e.g., *Tamarix*, *Prosopis*. Leaves or leaflets are often small, vertical, thick and leathery. They have either reflecting surfaces, (e.g., *Nerium*) or possess a coating of hair (e.g., *Gnaphalium*, *Aerua*). In grasses the leaves roll up during dry weather to reduce surface exposed for transpiration. In *Capparis decidua* the leaves are small and drought deciduous. In *Casuarina* the leaves are vestigial. Lamina is vestigial while petiole enlarges to form phyllode in Australian species of *Acacia*. Leaves may possess prickles and spines. The plants contain anthocyanins, resins, gums, latex, proline (an amino acid) and chaperonins. **Proline** is useful in maintaining osmotic and water potential. **Chaperonins** are heat shock proteins which protect other proteins from denaturation at high temperature. Cuticle is thick. Wax occurs. Stomata are sunken and restricted to lower surface of the leaves. Palisade parenchyma is more developed whereas spongy parenchyma is absent or reduced. Bark is thick and develops very early. Many tropical plants of hot and arid regions perform C_4 photosynthesis. They use less water and are adapted to perform high rate of photosynthesis even at high temperature.

Plant Adaptations to Aquatic Environment—Hydrophytes. Hydrophytes are of five types : submerged, suspended, free floating, floating leaved anchored and emergent hydrophytes. They possess special characteristics. (i) **Mucilage.** Hydrophytes are covered with mucilage which protects them from epiphytes, pathogens and animals. It also functions as lubricant. (ii) **Roots.** They are absent (e.g., *Utricularia*, *Wolffia*), poorly developed (e.g., *Hydrilla*, *Vallisneria*) or used for balancing (e.g., *Lemna*, *Pistia*, *Eichhornia*). Root hairs are absent or very few. Root caps are replaced by **root pockets**. (iii) **Mechanical Tissue.** It is absent. (iv) **Xylem.** It is poorly developed or absent. (v) **Aerenchyma.** Hydrophytes possess special air storage parenchyma called aerenchyma. It makes their different parts light, spongy and flexible. O_2 , produced during photosynthesis, becomes available to roots and other nonphotosynthetic regions. It can also help in exchange of gases with the atmosphere through stomata present in emerged regions. (vi) **Inflated Organs.** Special air storing organs occur in floating plants, e.g., roots in *Ludwigia* and petioles in *Eichhornia*. (vii) **Leaves.** Submerged leaves are thin, small, linear or finely dissected. Floating leaves are large, having stomata and waxy coating on the upper surface. Plants with both submerged and floating or emerged leaves show **heterophylly** or occurrence of more than one type of leaves, e.g., *Ranunculus aquatilis*, *Sagittaria*.

Plant Adaptations to Saline Environments—Halophytes. Halophytes are plants of saline habitats which have not only the ability to tolerate high concentrations of salts in their rooting medium but are able to obtain their water supply from the same. Halophytes grow in saline soils, mangroves, coastal dunes and tidal marshes. They have a high osmotic pressure, a minimum of 40 bars. Most halophytes possess succulence as well.

Plants of saline soils show characteristics of xerophytes e.g., *Sueda*, *Salsola*, *Salicornia*, *Tamarix*, *Atriplex*, *Spartina*. They may have succulence in leaves, stems or both. The succulent parts have large size cells which store water and mucilage. Though it is a means of storing and retaining water, succulence also helps in diluting salts. Many halophytes actually secrete salts through **chalk** or **salt glands**, e.g., *Atriplex*, *Spartina*. *Tamarix* also excretes salts but directly through epidermis. Thick cuticle, sunken stomata, anthocyanin and tannins occur to reduce insolation and prevent desiccation. Proline and other organic solutes may also occur.

Mangroves are marshy areas found in tropical deltas and saline ponds near sea shore.

The areas have not only excess salt but also excess water or anaerobic conditions besides difficulty in anchoring and seed germination. Plants growing in mangroves are halophytes. Many of them excrete salts with the help of salt secreting glands present over their leaves, e.g., *Avicennia*, *Aegialitis*. A few mangrove plants secrete salts from their roots. Some have water storage tissues to dilute salt, e.g., *Rhizophora* (Red Mangrove), *Avicennia*. Cuticle is thick. Some leaves have corky cells. Stomata are sunken or protected. Hair may occur. Anthocyanins, tannins and oil occur to reduce insolation. Proline and sorbitol are organic solutes often found in these plants for osmoregulation. A green alga *Dunaliella* found in hypersaline lakes, possesses a lot of glycerol in its cells for osmoregulation. Mangrove plants are supported in marshy areas by supporting roots — horizontal roots, knee roots, buttress roots, stilt roots, prop roots, etc. Lenticels occur for gaseous exchange. A number of plants possess small negatively geotropic vertical roots called **pneumatophores**. Pneumatophores have lenticels for gaseous exchange. They are connected with internal aerenchymatous tissue. Another adaptation of mangrove plants is **vivipary** or **seed germination while attached to plants**. The seedling grows sufficiently before it falls into the saline marsh. Only the radicle part passes into mud or water while the plumule part remains above the surface of water, e.g., *Rhizophora*, *Aegiceras*, *Ceriops*.

Plant Adaptations to Oligotrophic Soils. Oligotrophic soils are poor in nutrients. One such type of soil which supports dense vegetation is the one found in tropical rain forests. Here the top soil is shallow while subsoil has dense clay mixed with iron–aluminium compounds. Despite growing in oligotrophic soil, nutrient accumulation is high in vegetation. More than 84% of nutrients undergo biogeochemical circulation. A major adaptation of tropical plants is the presence of **mycorrhizae**. Mycorrhiza is a mutualistic association of plant roots with fungi. The association occurs in 83% dicots, 79% monocots and nearly all gymnosperms (Wilcox, 1991). It is useful in retrieval of critical elements from organic compounds (e.g., Phosphorus), absorption of water and protection from soil borne pathogenic fungi. Mycorrhizae are of two types (i) **Endomycorrhiza**. Fungus sends hyphal ends into cortical cells as vesicles and arbuscules (branched masses). Therefore, these are also called vesicular–arbuscular mycorrhizae or VAM. Intercellular hyphae and external hyphae are present but are fewer. Endomycorrhiza occurs in herbaceous angiosperms (Smith *et al.*, 1997) and some tropical trees. The fungus partner is generally azygomycete. A fungus can form endomycorrhizal association with several plants. (ii) **Ectomycorrhiza**. The fungus forms a mantle on outside and intercellular hyphae in cortex of root. Host secretes nutrients in intercellular spaces. Ectomycorrhizae occur in several trees and shrubs of temperate areas and some tropical species as well, e.g., Pine, Oak, *Eucalyptus*. The fungus partner is commonly a basidiomycete, occasionally an ascomycete. It is mostly host specific.

Animal Adaptations

Animals have adaptations to (i) Particular feeding habit like carnivory and herbivory. (ii) Protection from predators. (iii) Camouflage for easy predation. (iv) Structural and behavioural adaptation to attract mate, e.g., bright plumage of male birds. (v) Physiological and behavioural adaptation to environmental variations and stress conditions, e.g., migration, hibernation, aestivation, camouflage, mimicry, echolocation, water scarcity, prevention of freezing.

(1) **Migration.** It is a two-way movement of an animal group to other places for food, climate and other reasons. Migration is of three types— daily, seasonal, periodic. **Daily migration** occurs between feeding and resting places. **Seasonal migration** occurs for avoiding stressful and inhospitable seasons like winter. The distance travelled may be short

or long. The longest distance travelled by an animal is that of sea bird Arctic Tern (*Sterna parasissaea*). It nests in North Pole during summer but flies to Antarctica during autumn to return to North Pole during spring. The distance travelled is 17,600 km. Golden Plover (*Pluvialis dominica*) is a winter visitor in India. It flies nonstop for 3600 km and uses only 2 ounces of high octane fuel. Birds use position of sun, moon, stars and magnetic field for direction and navigation.

Caribou, Elk and Whales migrate during winter to warmer places for search of food. In Africa, wild beasts travel long distances along the geographical pattern of seasonal rainfall and hence availability of fresh vegetation. **Periodic migration** occurs in locusts when their number increases beyond the feeding capacity of the homeland. Large populations migrate in search of food to various directions. Sea Lamprey (*Petromyzon marinus*) migrates from sea to ascend rivers for spawning (anadromous). On the other hand Eel (*Anguilla bengalensis*) migrates to sea for spawning (catadromous).

Table 13.3. Migration as a strategy of Adaptation in Animals

Type of migration	Examples	Activities
Long-distance	Arctic Tern	Nests close to north pole in summer; flies south to Antarctica in autumn; returns to north pole again each spring.
Short-distance	Many birds Caribou, elk and whales	Birds migrate by using sun, moon, stars or magnetic field for direction and navigation.
Periodic	Locust	Migrate in search of food each winter to warmer places. Large populations migrate in search of feeding grounds.

(2) **Camouflage** (Cryptic Appearance). It is the ability to blend with the surroundings or background. It is the most common type of adaptation by animals to remain unnoticed for protection or aggression, e.g., many insects, reptiles and mammals. It is difficult to distinguish leaf like grasshopper (*Arantia rectifolia*) or Praying Mantis (*Mantis religiosa*) from the surrounding foliage. Similarly, Stick Insect (= Walking stick, *Carausius morasus*), Leaf Insect (*Phyllium frondosum*) and Dead Leaf Butterfly (*Phyllocrania paradoxa*) cannot be noticed unless and until they show movement. Camouflage is protective to animals which are preyed upon by others. It is advantageous in predation for predators like Praying Mantis as they remain unnoticed till the prey comes within their striking range. **Tenebrinoid beetles** feign death, become motionless and pebble like on sensing an approaching danger from predators.

(3) **Mimicry**. It is resemblance of one species with another in order to obtain advantage, especially against predation. The species which is imitated is called **model** while the animal which imitates is known as **mimic** or **mimetic**. Model is either ferocious or distasteful to predator. Mimicry is of two types, Batesian and Mullerian. (i) **Batesian Mimicry**. The mimic is defenseless. It has, however, resemblance to a dangerous or unpalatable model so that the predator usually does not prey upon it, e.g., Viceroy Butterfly (*Basilarchia archippus*) mimics unpalatable toxic Monarch Butterfly. (ii) **Mullerian Mimicry**. It is resemblance of two animal species, especially insects, both unpalatable or ferocious, to their mutual benefit, e.g., Monarch Butterfly and Queen Butterfly.

Some predators enhance chances of catching prey by alluring them (**alluring aggressive mimicry**). Mouthcorner of African Lizard appears like a flower. Many spiders resemble orchid flowers. Camouflage by predator that helps it to easily pick up its prey is called

concealing aggressive mimicry. Concealing camouflage of animals like Stick Insect, Leaf Insect or Dead Leaf Butterfly is also known as concealing or **cryptic appearance mimicry.**

Differences between Camouflage and Mimicry

Camouflage	Mimicry
1. It is the ability of animals to blend with the background.	1. It is resemblance of one species of animals with another species.
2. Camouflage allows the animals to remain unnoticed from a distance.	2. Mimicry hides the true identity of the animal species.
3. It is advantageous to both prey as well as predator.	3. It is advantageous to mimics against predation.

(4) **Warning Colouration.** Dart frogs (*Phylllobates bicolour*; *Dendrobates pumilio*) found in tropical rain forests of South America are highly poisonous as well as brightly coloured to be easily noticed. Predators usually avoid them.

(5) **Echolocation.** Bats are nocturnal flying mammals which do not employ eyesight for location of their path, food, place of rest, etc. They produce high frequency sound which produces echoes after striking various objects on the principle of sonar. Echoes are analysed by the bats to know their path. Echolocation is also used by other animals, e.g., whale.

(6) **Hibernation and Aestivation.** Hibernation or winter sleep and aestivation or summer sleep are quite common in ectothermal (cold blooded) animals. They, however, also occur in those warm blooded or endothermal animals which do not migrate from area of intense cold or heat. Frog, an ectothermal animal, shows both hibernation and aestivation. Northern Ground Squirrels, endothermal mammals, undergo hibernation during winter. During hibernation their body temperature drops but remains above the outside atmosphere. Breathing and heart beat become slow to reduce consumption of stored food. Endothermal Ground Squirrels of South-Western deserts undergo aestivation and lie in torpid or listless state inside the burrows during hot dry periods.

(7) **Diapause (Suspension).** Many zooplankton and larvae of some insects suspend their development in periods of stress. They undergo perennation. On the approach of favourable periods, development is resumed.

(8) **Adaptations to Excessive Cold (Cold Hardening).** Warm blood animals of colder areas have larger size as compared to hotter areas (Bergman's rule). Fishes of colder sea similarly have larger size often with larger number of vertebrae (Jordan's rule). Birds of colder areas have narrow and acuminate wings (Rensch's rule) as compared to broader wings of birds of warmer areas. Animals of colder areas possess thick fur, subcutaneous fat and small extremities (Allen's rule). They help in conservation of heat. During excessive cold they may undergo hibernation. However, sea animals cannot undergo hibernation. Sessile animals cannot migrate. These and some other animals protect themselves from excessive cold by developing cold hardiness, e.g., barnacles and molluscs of intertidal zones of cold areas, several insects and spiders. Cold hardiness is achieved by developing extra solutes in the body fluids and special ice nucleating proteins in the extracellular spaces. The extra solutes which prevent freezing are glycerol and antifreeze proteins. They lower the freezing point of body fluids. Ice Fish (*Chaenocephalus*) or Antarctic Fish (*Trematomus*) remains active even in extremely cold sea water due to this hardiness.

(9) **Adaptation of Water Scarcity.** Animals faced with water scarcity as found in arid or desert areas, show two types of adaptations—reducing water loss and ability to tolerate arid conditions. Kangaroo/Desert Rat seldom drinks water. It has a thick coat to minimise evaporative desiccation. The animal seldom comes out of its comparatively humid and cool burrow during the day time. 90% of its water requirement is met from metabolic water

(water produced by respiratory breakdown of fats) while 10% is got from food. Loss of water is minimised by producing nearly solid urine and faeces. Camel has a number of adjustments to desert conditions — economical in water consumption, minimising surface exposure, tolerance to fluctuations of temperature, no sweating till body temperature rises to 55°–66°C, maintenance of blood stream moisture with body cells capable of tolerating upto 40% dehydration. The animal produces dry faeces and concentrated urine. During period of nonavailability of water the animal stores urea and does not produce urine. When water is available, camel can rehydrate itself quickly by drinking large quantity of water, some 80 lts in 10 minutes.

(10) **Behavioural Adaptations in Desert Lizards.** Some organisms show behavioural adaptations to cope with variations in their environment. Desert lizards lack the physiological ability that mammals have to deal with the high temperature. They keep their body temperature fairly constant by behavioural means. They enjoy in the sun and absorb heat when their body temperature drops below the comfort zone, but move into shade when the surrounding temperature starts increasing. Some species are capable of burrowing into the soil to hide and escape from too much heat.

(11) **Physiological or Phenotypic Adaptations.** Some organisms have **phenotypic adaptations** which allow them to respond quickly to an unfavourable situation. If you had ever been to any high altitude (>3,500 m) place (say Leh, Rohtang Pass near Manali, Mansrover in Tibet) you must have experienced what is called **altitude sickness**. Its symptoms include nausea, fatigue and heart palpitations. It is due to the low atmospheric pressure of high altitudes that the body does not get enough oxygen. However, gradually we get accustomed and stop experiencing altitude sickness. *How did our body solve this problem?* The body compensates low oxygen availability by increasing red blood cell production, decreasing the binding capacity of haemoglobin (through increasing 2, 3-biphosphoglyceric acid) and by increasing breathing rate. Many tribes living in the high altitude of Himalayas normally have a higher count of haemoglobin than people living in the plains. Deep sea organisms are adapted to tolerate pressure of more than 100 atm. Microbes like **archaebacteria** live comfortably in hot springs and deep sea hydrothermal vents where temperature may exceed 100°C.

Table 13.4 Behavioural Strategies of Adaptations in Animals

Type	Examples	Processes and activities
Hibernation	Northern Ground Squirrels	True hibernators go into sleep during winter; body temperature drops; breathing and heartbeat become slow.
Aestivation	Ground Squirrels in south-west deserts	Avoid heat by spending dry-hot period in a torpid state into burrows.
Cryptic appearance (camouflage)	Leaf-like Grasshopper (<i>Arantia rectifolia</i>) Praying Mantis (<i>Phyllocrania paradoxa</i>)	Grasshopper resembles the complete leaf, Green resembles twigs and leaves of background vegetation or appears to be a part of leaf.
Dead Leaf Butter fly		Mimics a dead leaf
Batesian mimicry	Monarch Butterfly and the mimic Viceroy Butterfly	Monarch Butterfly (contains toxins in the body) and mimicked by Viceroy Butterfly (contains no toxins).
Mullerian mimicry	Monarch Butterfly and the mimic Queen Butterfly	Both butterfly species look similar and are also distasteful.
Echolocation	Horseshoe bat	Produces high frequency sounds; detects the presence of the echoes produced from the objects on the principle of sonar.

Allen's Rule. According to Allen's Rule, in endothermal animals of colder areas, the extremities like feet, tail, ears, etc. tend to be smaller as compared to their relatives in warmer regions. This minimises heat loss.

Differences between Diapause and Hibernation

Diapause	Hibernation
<ol style="list-style-type: none"> 1. It is a dormant stage in the development of an organism. 2. It occurs both in summer and winter. 3. During this period there is reduction in the amount of free water. 	<ol style="list-style-type: none"> 1. It is a state of inactivation in a ectothermic mature organism. 2. It occurs only in winter. 3. There is no such adaptation.

Differences between Hibernation and Aestivation

Hibernation	Aestivation
<ol style="list-style-type: none"> 1. It is winter sleep in which animal passes the winter period in dormant condition. 2. The animal rests in a warm place. 3. It is of longer duration and lasts for the whole duration of winter. 	<ol style="list-style-type: none"> 1. It is summer sleep. 2. Animal rests in a cool/shady and moist place. 3. It lasts for hot dry day time as nights are cooler.

Differences between Ectotherms and Endotherms

Ectotherms	Endotherms
<ol style="list-style-type: none"> 1. These are cold blooded poikilothermal animals. 2. They are unable to regulate their body temperature which changes with change of temperature of environment. 3. These animals show hibernation (winter sleep) and aestivation (summer sleep), e.g., fish, frog, lizards. 	<ol style="list-style-type: none"> 1. These are warm blooded homeothermal animals. 2. They maintain their body temperature in every condition. 3. These two activities rarely occur in these animals, e.g., Aves, mammals.

POPULATIONS

Population Attributes

Population is the total number of interbreeding individuals of a species found in a geographical area, who share and compete for similar resources. Although the term interbreeding applies to sexual reproduction yet a group of individuals produced from even asexual reproduction is also considered a population. Examples of population are all the rats in an abandoned dwelling, teakwood trees in a forest tract, bacteria in a culture plate and lotus in a pond. Although an individual organism has to cope with a changed environment, it is at the population level that natural selection operates to evolve the desired traits. Population ecology is, therefore, an important area of ecology because it links ecology to population

genetics and evolution. A population has certain qualities (group characteristics) that an individual organism does not have. (i) An individual may have birth or death, but a population has **birth rate** and **death rate**. In a population these rates refer to **per capita** births and deaths, respectively. For example, if in a pond there are 20 lotus plants last year and through reproduction 8 new plants added, taking the current population to 28, we calculate the birth rate as $8/20 = 0.4$ offspring per lotus per year. If 4 individuals in a laboratory population of 40 **fruitflies** died during a specified time interval (say a week), the death rate in the population during that period is $4/40 = 0.1$ individuals per fruitfly per week.

(ii) Another important characteristic of a population is **sex ratio**. An individual has sex (male or female) but a population has a sex ratio (e.g., 60% of the population are females and 40% males).

Differences between Population and Community

Population	Community
1. It is a grouping of individuals of a single species found in an area.	1. It is grouping of individuals of different species found in an area.
2. All the individuals of a population are morphologically and behaviourly similar.	2. Different members of a community are morphologically and behaviourly dissimilar.
3. Individuals of a population interbreed freely.	3. Interbreeding is absent amongst different members of a community.
4. It is a small unit of organization.	4. It is larger unit of organization.
5. There is no relationship of eating and be eaten.	5. In a biotic community there is often a relationship of eating and being eaten.

Age Distribution. A population has three **ecological age groups**— pre-reproductive, reproductive and post-reproductive (Bodenheimer, 1958). Their comparative abundance determines the reproductive status of population. A population having larger number of young individuals will show rapid increase (positive growth). It will have a slow increase or become static (zero growth) if various age groups are evenly balanced. A population with large number of post-reproductive or older individuals and lesser number of pre-reproductive individuals will show a negative growth rate (Fig. 13.14).

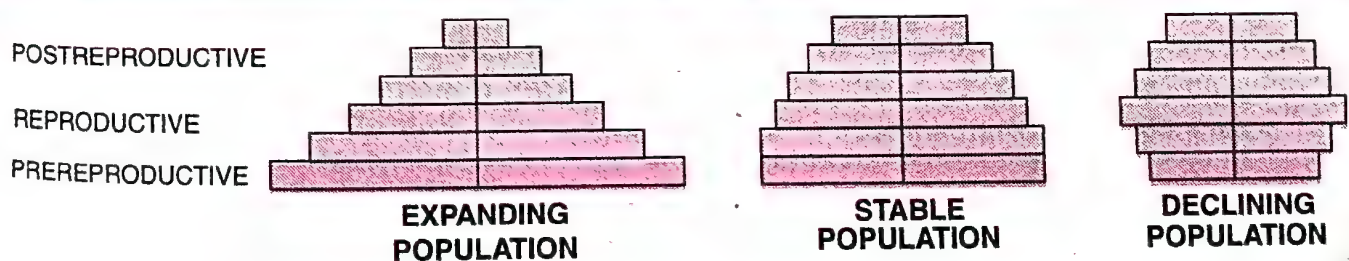


Fig. 13.14. Representation of age pyramids for human population.

Age Pyramids. Graphic representation of different age groups found in a population with pre-reproductive groups at the base, reproductive ones in the middle and post-reproductive groups at the top is called age pyramid. Age pyramids are of three types—

(i) **Triangular Age Pyramid.** The number of pre-reproductive individuals is very large.

Number of reproductive individuals is moderate while post-reproductive individuals are fewer. Population is growing. Rate of growth depends upon the comparative size of pre-reproductive population.

(ii) **Bell Shaped Age Pyramid.** The number of pre-reproductive and reproductive individuals is almost equal. Post-reproductive individuals are comparatively fewer. The population size remains stable, neither growing nor diminishing.

(iii) **Urn Shaped Age Pyramid.** Proportion of reproductive age group is higher than the individuals in pre-reproductive age group. Number of post-reproductive individuals is also sizeable. It is declining or diminishing population with negative growth.

Populations Size. The size of a population depends upon several factors like characteristic of the species (*ie.*, natality, mortality), carrying capacity of the environment, competition from other species, the impact of predator, or the effect of use of pesticide. The size in nature could be as low as less than 10 (Siberian cranes at Bharatpur wetlands in any year) or go into millions (*Chlymadomonas* in a pond). Population size, more technically called **population density** (designated as N) need not necessarily be measured in numbers only. Although the total number is most appropriate measure of population density, but in some cases it is difficult to determine. In a forest area, suppose there are 200 *Parthenium* plants but only a single huge banyan tree with a large canopy. Stating that the population density of banyan is low relative to that of *Parthenium* amounts to underestimating the great role of the banyan in that forest community. In such cases, the percent cover or biomass is a more meaningful measure of the population size. If the population is huge and counting is impossible or very time-consuming, the total number is not easily measured. If you have a dense laboratory culture of *Bacteria* in a petridish, only the biomass can be used as a measure of its density? Sometimes, for certain ecological investigations, there is no need to know the absolute population densities. Relative densities serve the purpose equally well. For example, the number of fish caught per trap is good enough measure of its total population density in the lake. Sometimes population size is indirectly estimated without actually counting them. The tiger census in our national parks and tiger reserves is often based on pug (animal's foot point) marks and faecal pellets.

Population Growth. The size of a population keeps changing depending on various factors including food availability, predation pressure, and adverse weather. In fact, these changes in population density give some idea of what is happening to the population, whether it is increasing or declining. Whatever may be the ultimate reasons, the density of a population in a given habitat during a given period changes due to changes in four basic processes, two of which (natality and immigration) contribute an increase in population density and two (mortality and emigration) to a decrease. The **population density** is the number of individuals of a species per unit area/space at a given time.

$$\text{Population Density (D)} = \frac{\text{Number of individuals (N)}}{\text{Space (S)}} \quad \text{or} \quad D = \frac{N}{S}$$

Population dynamics is the study of changing pattern of size, age, sex composition of population and the effect of environmental as well as biological processes driving these changes (*i.e.*, natality, mortality, emigration, immigration).

(i) **Natality.** It refers to the number of births during a given period in the population that are added to the initial density.

(ii) **Mortality.** It is the number of deaths in the population during a given period.

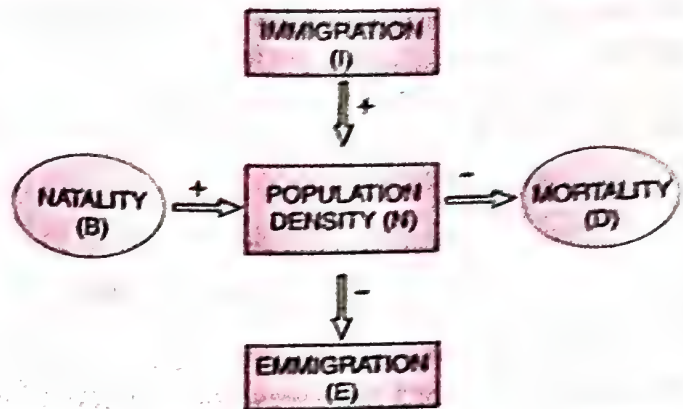
(iii) **Immigration.** It is the number of individuals of the same species that have come into the habitat from elsewhere during the time period.

(iv) **Emigration.** It is the number of individuals of the population who left the habitat and gone elsewhere during the time period.

Therefore, if N is the population density at time t , then its density at time $t + 1$ is

$$N_{t+1} = N_t + [(B + I) - (D + E)]$$

We can see from the above equation that population density increases if the number of births plus the number of immigrants ($B + I$) is more than the number of deaths plus the number of emigrants ($D + E$). Otherwise it will decrease. Under normal conditions, births and deaths are the most important factors influencing population density. However, if a new habitat is just being colonized, immigration may contribute more significantly to population growth than birth rates.



Differences between Natality and Mortality

Natality	Mortality
1. Natality is number of births per unit population per unit time, e.g., per thousand per year in humans.	1. It is number of deaths per unit population per unit time, e.g., per one thousand individuals per year in humans.
2. It adds new members to the population.	2. It removes individuals from the population.
3. It increases size of population.	3. It decreases size of population.
4. Natality adds to population density.	4. Mortality reduces density of population.
5. It maintains continuity of population.	5. It maintains health of the population.
6. It is high when population size is small and low when population size is large.	6. Mortality is low when population size is small and high when population size is large.

Differences between Immigration and Emigration

Immigration	Emigration
1. It is permanent inward movement of some individuals into a local population.	1. It is permanent outward movement of some individuals from a local population.
2. Size of local population increases.	2. Size of local population decreases.
3. There is entry of some new alleles into the gene pool.	3. There is loss of some alleles from the gene pool.
4. It is caused by availability of better living conditions.	4. It is caused by occurrence of deficiencies and calamities.

Growth Models. The growth of a population with time shows specific pattern. We are concerned about uncontrolled human population growth and problems created by it in our country. It is, therefore, essential to be curious if different animal populations in nature behave the same way. Perhaps we can learn from nature on how to control population growth.

(1) **Exponential Growth.** When food and space for a population are unlimited, each species has the ability to realize fully its inherited potential to grow, as Darwin observed while

developing his theory of natural selection. Then the population grows in an exponential or geometric ratio. If in a population of size N , the birth rates (not total number but per capita births) are represented as b and death rates (per capita death rates) as d , the increase or decrease in N during a unit time period t (dN/dt) will be

$$\begin{aligned} \frac{dN}{dt} &= (b - d) \times N \\ \text{Let } (b - d) &= r, \\ \text{then } \frac{dN}{dt} &= rN \end{aligned}$$

The r in this equation is called 'intrinsic rate of natural increase' and is very important parameter selected for assessing impacts of any biotic or abiotic factor on population growth.

To take some idea about the magnitude of r values, for the Norway rat the r is 0.015, and for the flour beetle it is 0.12.

In 1981, the r value for human population in India was 0.0205. To find out the current value of r you need to know the birth rates and death rates (e.g. 0.025 and 0.0081).

The above equation describes the exponential or geometric growth pattern of a population and results in a J-shaped curve when we plot N in relation to time (Fig. 13.15). If you know basic calculus, you can derive the integral form of the exponential growth equation as

$$N_t = N_0 e^{rt}$$

Where N_t = Population density after time t ; N_0 = Population density at time zero; r = intrinsic rate of natural increase; e the base of natural logarithms (2.71828)

If any species is growing exponentially under unlimited resources it can reach high population densities in a short time. Darwin showed how even a slow-growing animal like elephant could reach unlimited numbers in the absence of checks. Exponential growth is also called **J-shaped growth**.

(2) **Logistic Growth.** Unlimited resources result in exponential growth. Many countries have realized this fact and introduced various restraints to limit human population growth. In nature, a given habitat has resources to support a certain number of individuals of a population, beyond which no further growth is possible. This limit is called as nature's **carrying capacity** (K) for that species in that habitat.

A population growing in a habitat with limited resources shows initially a lag phase, followed by phases of increase and decrease and finally the population density reaches the carrying capacity. A plot of N in relation to time (t) results in a sigmoid curve. This type of population growth is called **Verhulst-Pearl Logistic Growth** (Fig. 13.15) as explained by the following equation :

$$\frac{dN}{dt} = r N \left(\frac{K - N}{K} \right)$$

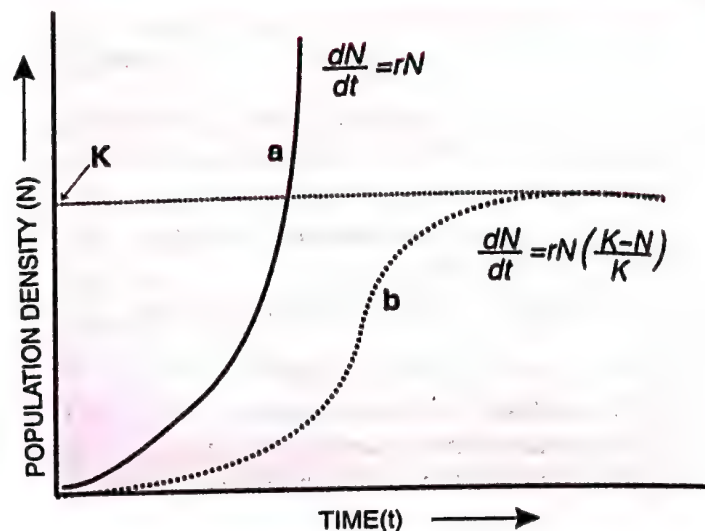


Fig. 13.15. Population growth curve *a* when responses are not limiting the growth, plot is exponential *b* when responses are limiting the growth, plot is logistic *k* is carrying capacity.

Where N = Population density at a time t ; r = Intrinsic rate of natural increase and;
 K = Carrying capacity

Since resources for growth for most animal populations become limiting sooner or later, the **logistic growth model** is more realistic. It is also called **S or sigmoid growth form**.

Differences between Exponential and Logistic Growths

Exponential or J-Shaped Growth	Logistic or Sigmoid Growth
<ol style="list-style-type: none"> 1. It occurs when the resources are abundant. 2. Population passes well beyond the carrying capacity of the ecosystem. 3. A stationary or steady phase is seldom achieved. 4. Population crashes ultimately due to mass mortality. 5. It has two phases, lag and log. 6. It occurs in fewer organisms, e.g., Lemmings, algal bloom. 	<ol style="list-style-type: none"> 1. It occurs when the resources are limited. 2. Population seldom grows beyond the carrying capacity of ecosystem. 3. A stationary or steady phase is reached. 4. Population seldom crashes. 5. It has four phases— lag, log, deceleration and steady. 6. It is more common, e.g., members of wildlife.

Census. Census is an official counting of population and preparing data about age groups, births, deaths, sex ration, education, etc. In India, first census was carried out in 1872, and since then, it has been conducted regularly at interval of ten years, the last being in 2001. Census is conducted as per the provision made under the Census Act, 1948.

Details of India's 15th Census 2011

India's Population as on March 1, 2011	: 1,210,193,422
Males	: 623,724,248
Females	: 586,469,174
Sex Ratio	: 940.27 females per 1,000 males.

Among states Kerala has the highest sex ratio (1084) and Daman the lowest (618).

Growth of Population : 2001–2011. Decadal (decade— period of ten years) growth rate of population between 2001-2011 at 17.64 per cent, is lower than 21.34 percent recorded between 1991-2001.

The Population Density : 382 persons per Sq. Km.

The Most Thickly Populated State : Bihar followed by West Bengal

If Delhi is considered a state, Delhi is the most thickly populated state/city in India with 11,297 persons per Sq. Km.

Most Populous State : Uttar Pradesh

Least Populous State/UT : Lakshadweep

Literacy Rate : 74.04 per cent (82.14 for males and 65.46 for females).

The Highest Literacy Rate : Kerala with 93.91 per cent literacy rate.

The Lowest Literacy Rate : Bihar with 63.82 per cent literacy rate.

Population of India 1901–2011	
Year	Population
1901	238, 396, 327
1911	252, 093, 390
1921	251, 321, 213
1931	278, 977, 238
1941	318, 660, 580
1951	361, 088, 090
1961	439, 234, 771
1971	548, 159, 652
1981	685, 148, 692
1991	843, 930, 861
2001	1,027,015,247
2011	1,210,193,422

Sex Ratio in India 1901–2011	
Year	Females per 1000 males
1901	972
1911	964
1921	955
1931	950
1941	945
1951	946
1961	941
1971	930
1981	934
1991	927
2001	933
2011	940.27

Exponential model does not have carrying capacity because responses are not limiting the growth plot.

Life History Variation. Populations evolve to maximise their **Darwinian fitness** (high r value) in their habitat. It is known that in nature (i) some species live very long (e.g., humans), some only for a short time (e.g., insects), (ii) some breed only once in their life time (e.g., Pacific salmon fish, bamboo) while others breed many times during their lifetime (e.g., most birds and mammals), (iii) some produce a large number of small-sized offspring (e.g., Oysters, pelagic fishes) while others produce a small number of large-sized offspring (e.g., birds, mammals). So, which is maximum fittest to their surroundings? Ecologists suggest that life history traits of organisms have evolved due to the abiotic and biotic components of their habitat. Evolution of life history traits in different species is important. Therefore, it requires further research.

R and K Selection. They are two types of population growth. In **r-selection**, resources are abundant, natality is high, size of individuals is small but the population seldom reaches carrying capacity due to high degree of predation, e.g., Rabbit. In **k-selection**, though natality is low, the individual size is large, longevity is high so that population exists at the carrying capacity, e.g., Wolf. Group loyalty and parenting are lacking in r-selection. They are well developed in k-selection.

Population Interactions

There is no natural habitat on earth that is inhabited by single species. For any species, the minimal requirement is one more species on which it can feed. Even a plant species, which makes its own food, cannot survive alone, it needs soil microbes to breakdown the organic matter and return the inorganic nutrients for its use. The plant manages pollination with an animal agent. Animals, plants and microbes do not and cannot live in isolation but interact in various ways to form a biological community. Interspecific interactions arise from the populations of two different species. They could be beneficial, harmful or neutral (neither harm nor benefit) to one of the species or both. Assigning a+ sign for beneficial interaction. – for harmful and 0 for neutral interaction various types of interactions are given in table 13.3.

Table 13.5. Interaction Amongst Different Species

Interaction	Effect on Species A	Effect on Species B	Nature of Interaction
<i>With Negative Effect</i>			
1. Predation	(+)	(-)	Predator (generally larger) destroys the prey.
2. Competition			
(a) Direct	(-)	(-)	Mutual inhibition
(b) Indirect	(-)	(-)	Inhibition due to short supply of resources.
3. Parasitism	(+)	(-)	Parasite (usually smaller) benefitted, host harmed.
4. Amensalism	(-)	Nil	One inhibited, other unaffected.
5. Commensalism	(+)	Nil	Commensal benefitted, other unaffected.
<i>With Positive Effect</i>			
6. Protocooperation	(+)	(+)	Beneficial to both, not obligatory.
7. Mutualism (Symbiosis)	(+)	(+)	Beneficial to both, obligatory.

1. Predation

Definition. It is an interaction between members of two species in which members of one species capture, kill and eat up members of other species. The former are called **predators** while the latter are spoken as **preys**.

Examples. Predators are mostly animals. Carnivorous animals eat up other animals. Herbivorous animals, which either eat parts or seeds of plants are in a way also predators because they remove individuals or future individuals from the population. A few plants are also predator in nature. They are called **carnivorous** or **insectivorous plants**, e.g., *Utricularia*, *Dionaea*, *Drosera*, *Nepenthes*.

Examples of simple predation include tigers and deer, frogs and insects, owls and rats, sea snake and eggs. The relation between land snake and rat is more than that of predator-prey as the snake also uses rat hole as shelter. Rufus Woodpecker (*Micropternus branchyurus*) not only feeds on ferocious red ants but also digs a hole in their bell-shaped nest for living in their company. Even its eggs and young ones are not harmed.

For plants, herbivores are the predators. Nearly 25% of all insects are known to be **phytophagous** (feeding on plant sap and other parts of plants). The problem is particularly severe for plants because, unlike animals, they cannot run away from their predators. Plants, therefore, have evolved an astonishing variety of morphological and chemical defences against herbivores. Thorns and spines (*Acacia*, *Cactus*) are the most common morphological means of defence. Many plants produce and store chemicals that make the herbivore sick when eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it. You must have seen the weed *Calotropis* growing in abandoned field. The plant produces highly poisonous cardiac glycosides. That is why you never see any cattle



Fig. 13.16. A hawk predating over a small bird like sparrow.

or goats browsing on this plant. A wide variety of chemical substances that we extract from plants on a commercial scale (Nicotine, caffeine, quinine, strychnine, opium, etc.) are produced by them actually as defences against grazers and browsers.

Some species of insects and frogs are cryptically coloured (camouflage) to avoid being detected easily by the predator. Some are poisonous and, therefore, avoided by the predators. The Monarch butterfly is highly distasteful to its predator (bird) because of a special chemical present in its body. Interestingly, the butterfly acquires this chemical during its caterpillar stage by feeding on a poisonous weed.

Adaptations. Some predators function as preys for others, e.g., frog (feeding on insects) for snake, snake (feeding on frogs and rats) for eagle or peacock. Predators have special adaptations to capture and eat the prey. They include agility, strength, catching and tearing organs.

Importance of Predation

(i) **Prey Population.** In nature the population of predator is quite small as compared to that of the prey so that the latter is never eliminated completely. The prey has high reproductive potential. If the latter is maintained for some period without predation, the population of prey individuals would go beyond the carrying capacity of the environment. The individuals would then become weak and the species undergo degeneration with time. The predator keeps the population of the prey under check so that an equilibrium is maintained. The prey also maintains its optimum activity and efficiency since only weak and sick individuals are removed by the predators.

(ii) **Biological Control of Weeds and Pests.** It is largely based on predator prey relation. Thus *Opuntia* turned out to be serious weed in Australia. It was brought under control when its natural herbivore *Cactoblastis* was introduced. Red locust menace was controlled in Mauritius by the introduction of Mynah from India. Aphids and other pests are kept under check by beetles (e.g., *Coccinella* or Lady Bird Beetle) and other insects, the latter by birds and so on. Fish *Gambusia* is introduced in ponds to check growth of mosquito larvae.

The prickly pear cactus (*Opuntia*) introduced into Australia in the early 1920's caused havoc by spreading rapidly into millions of hectares of rangeland. Finally the invasive cactus was brought under control only after a cactus-feeding predator (a moth) from its natural habitat was introduced into the country. **Biological control** methods adopted in agricultural pest control are based on this prey-regulating ability of the predator.

(iii) **Species Diversity.** Predators also help in maintaining species diversity in a community, by reducing the intensity of competition among competing prey species. In the rocky intertidal communities of the American Pacific Coast the starfish *Pisaster* is an important predator. In a field experiment, when all the starfish were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year.

(iv) **Vegetation.** Predation helps in growth of vegetation all over the globe by restricting the population of herbivores.

2. Parasitism

Definition. It is a relationship between two living organisms of different species in which one organism called **parasite** obtains its food directly from another living organism called **host**. The parasite is smaller as compared to its host. It spends a part or whole of its life on or in the body of the host.

Types of Parasites. There are six categories of parasites:

(a) **Ectoparasites and Endoparasites.** Ectoparasites live over the surface of their host while endoparasites live inside the host body. Ectoparasites suck blood (in case of animals e.g., sucking lice, fleas) or juice (in case of plants e.g., aphids), feed on living tissue (e.g., Scab mites) or dead tissue (e.g., biting or bird lice). Endoparasites can be intracellular (e.g., malarial parasite), tissue parasites (e.g., *Trichinella*), body fluid parasites (e.g., *Trypanosoma*, *Microfilaria*), gut or cavity parasites (e.g., *Ascaris*, *Taenia*).

Differences between Ectoparasites and Endoparasites

<i>Ectoparasites</i>	<i>Endoparasites</i>
<ol style="list-style-type: none"> 1. Ectoparasites live on the surface of the host. 2. They can be temporary, intermittent or permanent. 3. They can be hemiparasites or holoparasites. 4. Respiration is aerobic. 5. Specialisation has led to loss of fewer structures, e.g., wings in fleas, bedbugs and lice. 	<ol style="list-style-type: none"> 1. Endoparasites live in the body of the host. 2. They are generally permanent parasites. 3. They are usually holoparasites. 4. Respiration is often anaerobic. 5. Specialisation has led to the loss of several structures, e.g., digestive organs in <i>Taenia</i>.

(b) **Temporary and Permanent Parasites.** Temporary parasites live in contact with host for only a part of their life or occasionally at the time of feeding (e.g., bed bug, leech). The latter are often called **intermittant parasites**. In fact, the female mosquito is not considered a parasite because it is a vector that transfers the parasite to the human beings. So it is a vector. Permanent parasites live in contact with host throughout their life. They are transferred to new host as egg, cyst or directly, e.g., *Ascaris*, *Entamoeba*, lice.

(c) **Holoparasites and Hemiparasites.** Holoparasites are those parasites which are completely dependent on the host for all their requirements, e.g., *Rafflesia*, *Cuscuta*, animal parasites. *Cuscuta* is known to receive even the flower inducing hormone or florigen from the host. It is, therefore, short day plant in contact with short day plant host and long day plant in contact with long day plant host. Hemi or semi-parasites are those parasites which receive only a part of nourishment from the host while the rest is manufactured by them e.g., *Viscum* (Mistletoe), *Loranthus*.

(d) **Stem and Root Parasites.** They are parasitic on plants and are in contact with the host plant either in the region of stem (e.g., *Cuscuta*, *Loranthus*, *Viscum*, stem borer, lac insect, aphids) or root (e.g., *Rafflesia*, root nematodes). Bacterial, fungal and viral parasites occur on all parts of the plants. The parasites which live in plants are called **phytoparasites**.

(e) **Pathogenic and Non-pathogenic Parasites.** Parasite may not harm the host either because it deprives the host of only a fraction of food or is dependent on the host for its dead tissues only. They are called non-pathogenic parasites, e.g., *Entamoeba coli*. Other parasites cause diseases in the host. They are known as pathogenic parasites, e.g., *Vibrio comma* (*V. cholerae*), *Corynebacterium diphtheriae* (diphtheria), *Mycobacterium leprae* (leprosy), rusts, smuts and powdery mildews of plants, fungal diseases, ringworm, etc.

(f) **Hyperparasite.** It is the name of parasite which lives on another parasite, e.g., some bacteriophages (bacterial viruses), *Cicinnobolus cesatii* (on powdery mildew), bacterium *Pasteurella pestis* in *Xenopsylla cheopsis* (Rat Flea) that is ectoparasite of Rat.

(g) **Intercellular Parasites.** They live in the cells of the host (human) e.g., malarial parasite.

(h) **Brood Parasitism in Birds.** Brood parasitism in birds is an interesting example of parasitism in which the parasitic bird lays its eggs in the nest of its host and the host incubates them. During the course of evolution, the eggs of the parasite bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest. Try to follow the movements of the cuckoo (koel) and the crow in your neighbourhood park during the breeding season (spring to summer) and watch brood parasitism in action.

Mode of Infection. The parasites may infect the new host by (i) boring through skin (hook worm), (ii) direct contact with infected persons (louse), (iii) introduction into the body with insect bite—tse tse fly bite (sleeping sickness), sandfly bite (kala azar) or mosquito bite (malarial parasite, filarial worm) and (iv) by swallowing cysts (*Entamoeba*), eggs (*Ascaris*) or larvae (tape worm).

Adaptations for Parasitic Life. The general parasitic adaptations are as follows :

(i) Anaerobic respiration in internal parasites. (ii) Loss of certain organs (e.g., lice, fleas and bedbugs lack wings, *Taenia* loses digestive system, *Sacculina* loses most of adult organs simultaneously causing **castration** of the host crab). (iii) Adhesive organs (e.g., suckers in leeches, tapeworms). (iv) Excessive multiplication (parasites produce innumerable young ones). (v) Resistant cysts and eggs for safe transfer of their progeny to new hosts. (vi) Well developed and complicated reproductive organs.

Differences between Predator and Parasite	
Predator	Parasite
1. It feeds on another organism called prey.	1. It feeds on another organism called host.
2. Predator is larger and stronger than the prey.	2. Parasite is smaller and weaker than the host.
3. It kills the prey.	3. Parasite does not immediately kill the host though the latter may die of prolonged exploitation.
4. Predator feeds on killed prey.	4. It feeds on living host.
5. It feeds over the prey from outside.	5. Parasite may feed over the host from outside or inside.
6. Predator comes in contact with prey for catching and eating.	6. It may have temporary or permanent contact with the host.
7. There is progressive development of characters or evolution.	7. Many of the characteristics undergo retrogression in the parasite.
8. In predator-prey relationship the stronger organism is benefitted.	8. In parasite-host relationship a weaker organism is benefitted.
9. Prey specificity is less common.	9. Host specificity is more common.

3. Amensalism

Definition. Amensalism is an interaction between two living individuals of different species in which an organism does not allow other organism to grow or live near it. Inhibition is achieved through the secretion of chemicals called **allochemicals**.

Examples. *Penicillium* does not allow the growth of *Staphylococcus* bacterium, *Trichoderma* the growth of fungus *Aspergillus* while *Convolvulus arvensis* inhibits the germination and growth of wheat. The crops of Barley, Sorghum and Sunflower are called **smoother crops** because they do not allow the weeds to grow nearby. Similarly, the roots and hulls of

Black Walnut (*Juglans nigra*) produce a chemical named **juglone**. It is a toxic to Apple, Tomato and Alfalfa. An older plant of *Grevillea robusta* does not allow its seedlings to grow nearby on account of allelochemicals produced by its roots. *Tagetes* secretes chemicals toxic to soil nematodes.

4. Commensalism

Definition. It is the relationship between two living individuals of different species in which one is benefitted while the other is neither harmed nor benefitted except to a negligible extent.

Examples. (i) The **pilot fish** (*Naucrastes ductor*) is a carnivorous commensal. It always accompanies **shark** without getting attached to the same. It feeds on falling pieces of food when the shark is eating the prey. (ii) **Sucker fish** (*Remora*, *Echeneis*) attaches itself to the under-surface of **shark** with the help of its dorsal fin which is modified into holdfast. Sucker fish gets a free ride. It is widely dispersed and remains protected from its predators. Sucker fish detaches itself from shark when the latter is feeding to obtain smaller pieces of food. (iii) **Jackals** follow a **lion** or **tiger** while arctic fox follows a seal for obtaining food from pieces or bits left by the predators. (iv) **Epiphytes** are small green plants which grow perched on larger plants for space only, e.g., orchids, mosses, some ferns. They are otherwise nutritionally independent. Epiphytes are called **space parasites**. They are benefitted while their space host is not harmed. Many animals disperse the seeds and fruits of plants which happen to stick to their fur either through mud or having special devices for attachment. The plants are benefitted but the animals are not harmed. (v) Some commensals may be slightly harmful or beneficial to the hosts. Thus *Escherichia coli* is commensal which feeds on undigested food inside the human intestine. It is believed to be beneficial because the bacterium checks the growth of putrefying bacteria and releases some vitamins for use by the human body. (vi) The relationship between **Sea Anemone** (*Adamsia palliata*) and **Hermit Crab** (*Eupagurus prideauxi*) is considered commensalism by some, mutualism by a few and protocoevolution by others. Sea Anemone is sedentary while Hermit Crab is free swimming. Hermit Crab resides inside an empty snail shell for protection. The sea anemone also uses snail's shell as a portable home. Sea Anemone is benefitted by this association in that it is able to find more food (Hermit Crab may also derive some benefit through protection provided by Sea Anemone because of the presence of stinging cells in the latter).

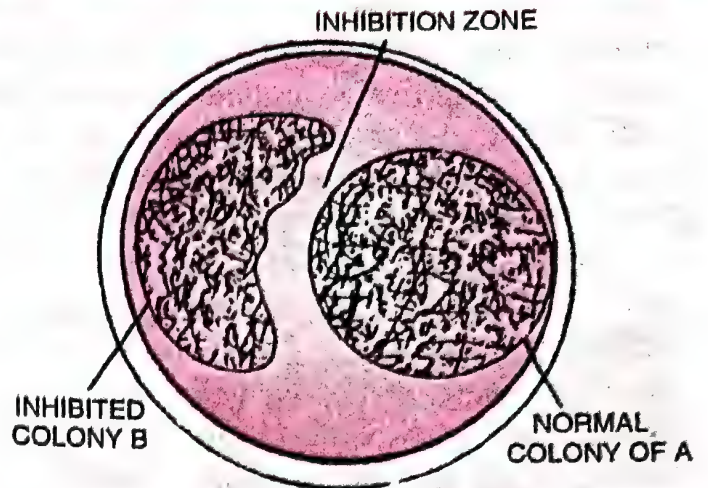


Fig. 13.17. Ammensalism between two colonies of micro-organisms.

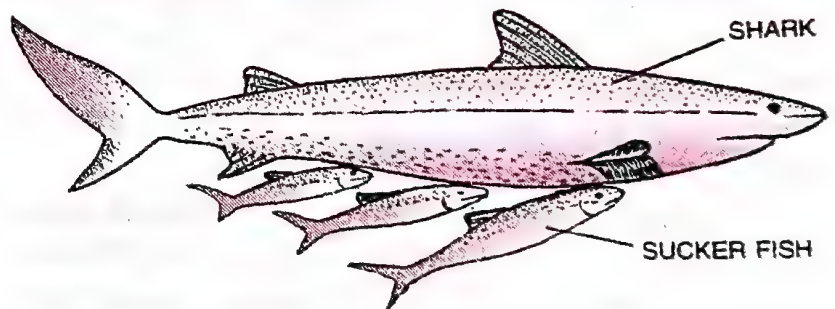


Fig. 13.18. Commensalism between Sucker Fish and Shark.

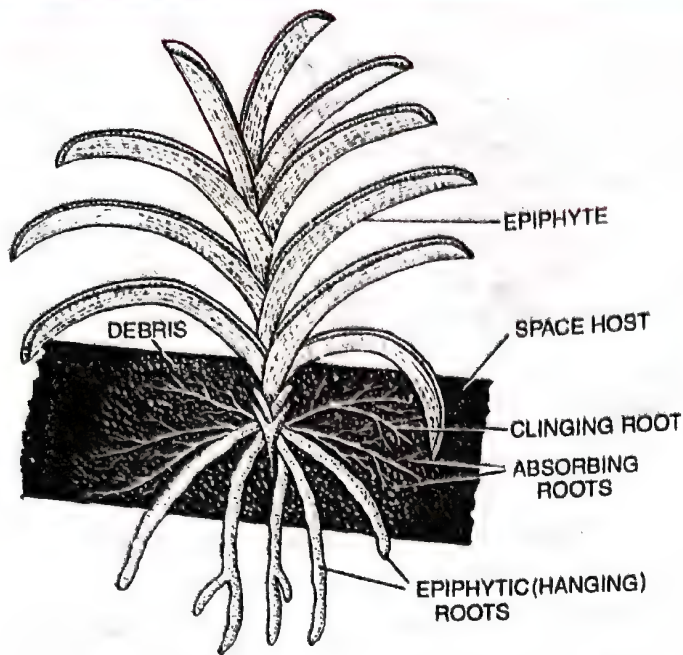


Fig. 13.19. An epiphyte growing on another plant for space only.

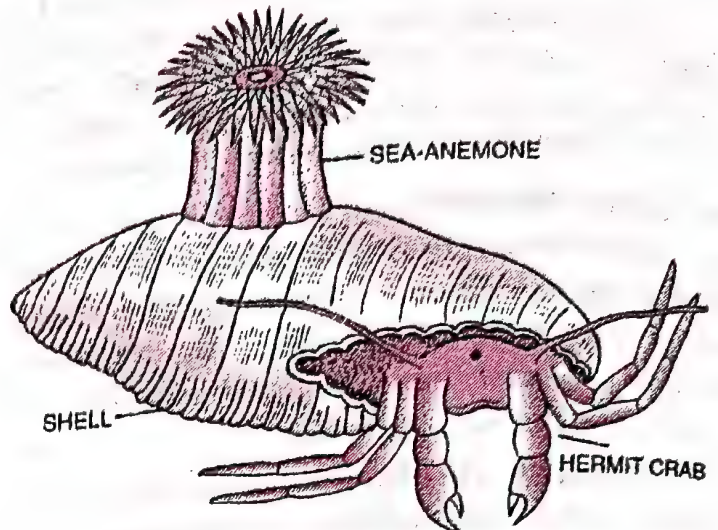


Fig. 13.20. Sea Anemone on snail's shell inhabited by a hermit crab.

5. Protocooperation

Definition. Protocooperation is interaction between two living organisms of different species in which both are mutually benefitted but they can live without each other. It is also called facultative mutualism.

Examples. (i) Red-billed Ox Pecker (*Buphagus erythrorhynchus*) and yellow-billed Ox Pecker (*Buphagus africanus*) form a protocooperation type of interaction with Black Rhinoceros (*Diceros dicornis*). The birds feed on ticks and other parasites sticking to the skin of Rhinoceros. The latter is relieved of the parasites. The birds also warn the Rhino of any approaching danger. (ii) Crocodile Bird (*Pluvianus aegyptius*) enters the open mouth of Crocodile and rids the latter of leeches.

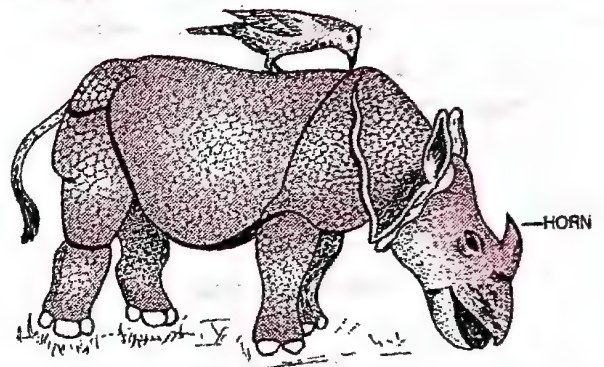


Fig. 13.21. Protocooperation between tick bird and Ox pecker and Rhinoceros.

6. Mutualism (Symbiosis)

Definition. Mutualism is an interaction between two organisms of different species where both the partners are benefitted with none of the two capable of living separately. Examples of symbiosis or mutualism are lichens, symbiotic nitrogen fixation, mycorrhizae, cellulose digestion in animals, pollination and seed dispersal. Mutualism and other types of interactions are possible only through **coevolution** or simultaneous changes in genetic composition of the interacting species that reciprocally suit each other, e.g., alga and fungus in lichen, flower and pollinator.

(i) **Lichen** is a composite entity which is formed jointly by an alga (phycobiont) and a fungus (mycobiont). The main body of the lichen is formed of fungus. The fungus also provides fixation, water, minerals and shelter to the alga. The alga manufactures food not

only for itself but also for the fungus. This interaction or relationship allows the lichen to grow in highly hostile environment like bare rock.

(ii) **Mutualistic nitrogen fixation** is widespread, e.g., root nodules of legumes *Alder* and *Casuarina*, leaf nodules of *Ardisia*, coralloid roots of *Cycas*, water fern *Azolla*, etc. Nitrogen fixation in legume root nodules is carried out by bacteria belonging to genus *Rhizobium*. The bacteria also live freely in the soil but are unable to fix nitrogen. Nitrogen fixation property develops only inside root nodules. The legume provides food and shelter to the bacteria. A major part of nitrogen fixed by bacteria is handed over to the legume. Thus both are benefitted. Nitrogen fixing blue-green alga or cyanobacterium called *Anabaena* is associated with water fern *Azolla* in a mutualistic interaction. A similar association occurs in the coralloid roots of *Cycas*.

(iii) **Mycorrhiza** is a mutualistic interaction in which a fungus (e.g., *Boletus*) and a root (e.g., *Pinus*) are involved. The root provides food and shelter to the fungus. The fungus helps the plant in solubilisation and absorption of minerals, water uptake and protection against pathogenic fungi.

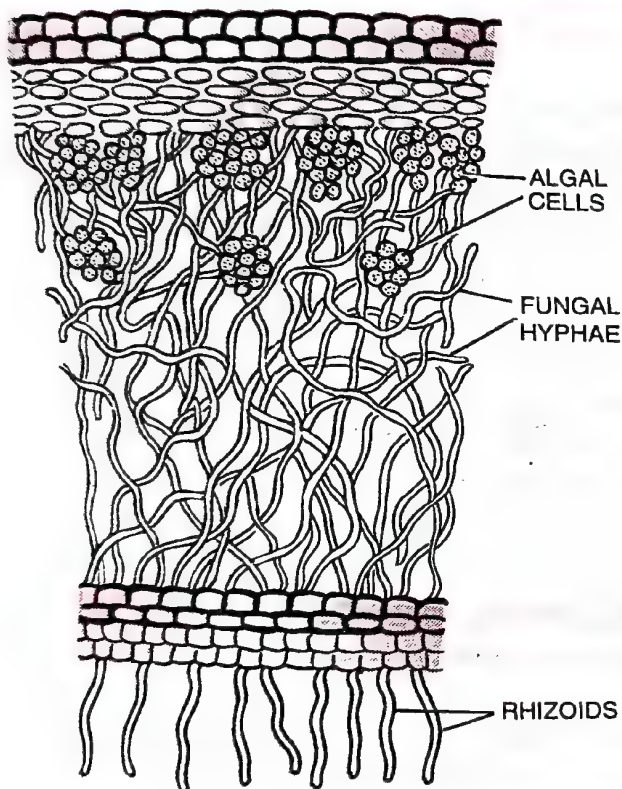


Fig. 13.22. Section of lichen showing algal and fungal partners.

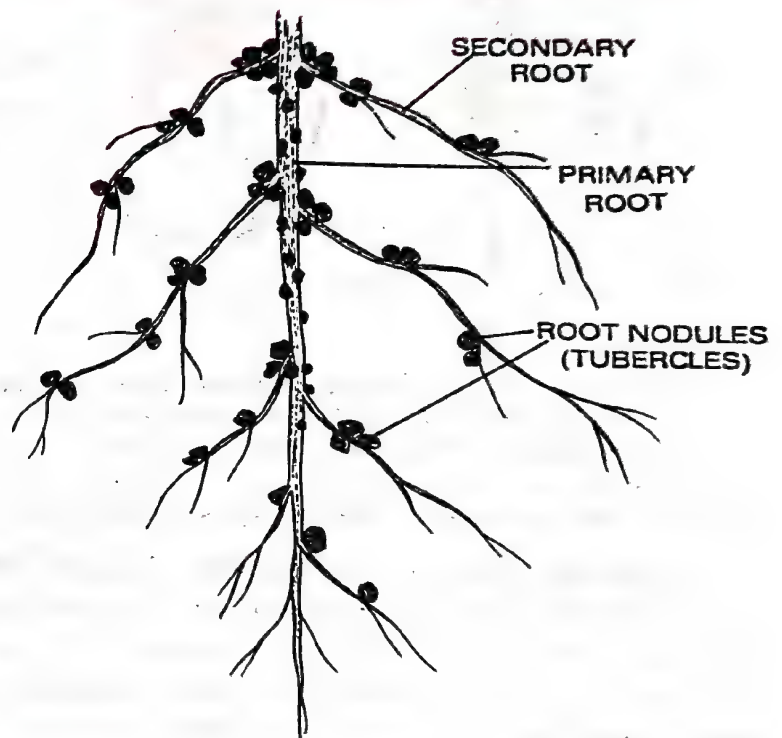


Fig. 13.23. Mutualism. Nodulated root system of a legume having nitrogen fixing *Rhizobium* bacteria in the nodules.

(iv) **Termites** feed on wood though they do not possess enzymes for digesting the same. Termites harbour cellulose digesting **flagellates** (e.g., *Trichonympha campanula*) for this purpose. Flagellates are unable to live independently. Termites would die of starvation in the absence of flagellates. Newly hatched termites receive the flagellates from the older termites through licking their anal area. At the time of moulting of termite, flagellate *Trichonympha* also forms cysts which are passed out alongwith moulting of gut. The moulting is eaten by termites to restore flagellate population.

(v) **Ruminant mammals** possess both ciliates (e.g., *Entodinium*) and bacteria (e.g., *Rumenococcus*) for cellulose digestion. The microorganisms obtain food and shelter. They take part in digestion of cellulose for the ruminant.

(vi) **Pollination and Seed Dispersal.** The most fascinating examples of mutualism are found in plant-animal relationships. Plants need the help of animals for pollinating their flowers and dispersing their seeds. Animals get rewards in the form of pollen and nectar for pollinators and juicy and nutritious fruits for seed dispersers.

In many species of fig trees there is a relationship with the pollinator species of wasp (Fig. 13.24). It means that a given fig species can be pollinated only by its partner wasp species and not other species. The female wasp uses the fruit not only as an oviposition (egg-laying) site but uses the developing seeds within the fruit for nourishing its larvae. The wasp pollinates the fig inflorescence while searching for suitable egg-laying sites. In return for the favour of pollination the fig offers the wasp some of its developing seeds as food for the developing wasp larvae.

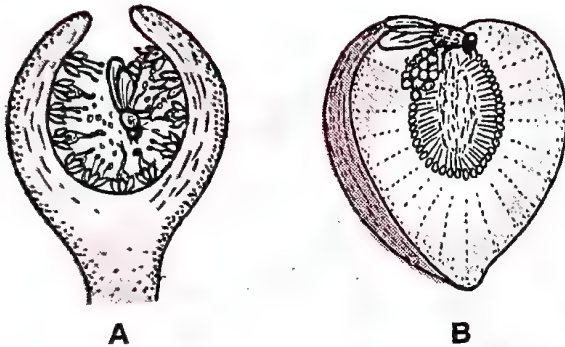


Fig. 13.24. Showing mutual relationship between fig tree and wasp. A. Fig flower is pollinated by wasp. B. Wasp laying eggs in fig fruit.



Fig. 13.25. Showing bee a pollinator on orchid flower.

In orchids, there is relationship with pollinator insects (bees and bumble bees; Fig. 13.25). The Mediterranean orchid *Ophrys* employs **sexual deceit** to get pollination done by a species of bee. One petal of its flower bears an uncanny resemblance to the female of the bee in size, colour and markings. The male bee is attracted to what it perceives as a female, **pseudocopulates** with the flower, and in that process pollinates the flower.

Differences between Mutualism and Commensalism

Mutualism	Commensalism
1. It is an association between two organisms in which both are benefitted.	1. It is an association between two organisms in which only one is benefitted. The second is neither benefitted nor harmed.
2. Contact between the two organisms is obligatory.	2. Contact between commensal and its benefactor may be periodic or continuous.

7. Competition

Definition. It is a rivalry between two or more organisms for obtaining the same resources.

Types. Competition is of two types. Competition between individuals of the same species is called **intraspecific** (= intranecine) competition while that between individuals of different species is termed as **interspecific** (= internecine) competition. Intraspecific competition is always more acute than interspecific one because all the members of a species have the similar requirements of food, light, water, space, shelter and mate. They also possess similar types of characteristics. Establishment of territories by animals is meant for ensuring availability of their needs. Similarly plants of the same species survive and grow favourably only when they are well-spaced. Intraspecific competition controls the size of population through decrease in the number of births and their survival. Thus flour beetle kept in pairs of 1, 8, 40 and 80 showed a corresponding decrease in the number of eggs from 10, 6, 2 and 1.

In interspecific competition two or more populations usually belonging to the same trophic level or feeding habit compete with one another for the natural resources. For example, in a forested area trees, shrubs, herbs and vines compete with one another for sunlight, nutrients, water, pollinators and dispersal agents. Carnivorous animals like tigers and leopards may compete for the same prey. However, the individuals of different species do not have similar types of adaptations. Various types of individuals prove their superiority or inferiority and adapt themselves differently to survive and obtain the same resources. However, if the resource is in short supply, the superior type of individuals will exclude the inferior types of individuals.

Gause's Hypothesis (=Principle of Competitive Exclusion). Gause (1934) found that out of two species of *Paramecium* grown together one is eliminated. This phenomenon is called Gause's hypothesis or **principle of competitive exclusion** (Hardein 1960). Sometimes, two or more species survive this competition. Thus *Poa pratensis* and *Agrostis alba* absorb K^+ from the medium so rapidly as to eliminate species of *Medicago* and *Brumus* growing nearby. In Galapagos islands, Abingdon tortoise became extinct within ten years of introduction of goat because the latter was more agile and better browser. Otherwise competition keeps the population of inferior species under check. In the rocky sea coast of Scotland, it was found by Connell that the superior barnacle *Balanus* nearly excluded the smaller barnacle *Cathamalus*. However, if population of *Balamus* is reduced, competition is released and *Cathamalus* increases in number. The phenomenon is called **competitive release**.

The competing species may coexist due to different specializations. Thus Darwin found fourteen species of finches to coexist in Galapagos islands due to development of different feeding habits. Similarly, in Serengeti plains over 20 species of antelopes graze in the same area. Several plants can grow together by sending their roots to various lengths. Therefore, competition does not always result in extinction of species but causes development of larger number of niches.

Differences between Intraspecific and Interspecific Competition	
Intraspecific Competition	Interspecific Competition
<ol style="list-style-type: none"> 1. It is competition among individuals of the same species. 2. The competition is for all the requirements. 3. The competing individuals have similar type of adaptation. 4. It is more severe due to similar needs and adaptations. 	<ol style="list-style-type: none"> 1. The competition is amongst the members of different species. 2. The competition is for one or a few requirements. 3. The competing individuals have different types of adaptations. 4. It is less severe as the similar needs are a few and the adaptations are different.

ADDITIONAL INFORMATION

- **Father of Plant Ecology is Warming.** He wrote the first book on plant ecology – 'Oecology of Plants' (1895).
- **Father of Indian Plant Ecology is Ramdeva Misra.** Ecological studies were initiated in India by W. Dudgeon.
- **Hexicology.** Term used by Mivart (1894) for ecology.
- **Bioecology.** Term used by Shelford and Clements for study of both plant and animal ecology.
- **Schroeter and Kirchner (1896).** Coined the terms autecology and syneecology.
- **Ecological Equivalents.** Different organisms occupying similar niches in different geographical areas.
- **Bergaman's Rule.** Birds and mammals of colder areas are larger in size as compared to their equivalents in warmer areas, *e.g.*, 1.0 m long Penguin in Antartica and 0.5 m long in Galapagos islands.
- **Ecophenes.** Habitat forms or ecads.
- **Acquifer.** Stratum containing ground water. **Water table** is upper layer of ground water.
- **Rensch's Rule.** Birds of colder areas have narrow and acuminate wings while those of warmer areas have broader wings.
- **Jordon's Rule.** Fish size as well as number of vertebrae increase in colder areas as compared to warmer areas.
- **Allen's Rule.** Animals of colder areas have shorter extremities (*e.g.*, tail, ears, feet) as compared to animals to warmer areas.
- **Indirect Factors.** They are factors which express their effect on organisms through direct factors, *e.g.*, wind, rainfall, soil texture.
- **Remote Factors.** The factors influence growth and distribution of organisms generally through indirect factors which in turn affect the direct factors, *e.g.*, topographic factors like altitude.
- **Crypsis (Cryptic Colouration; Gr. *crypt* meaning "hidden").** It is a type of colouration in which an animal helps to camouflage in its natural environment.
- **Ecesis** is the establishment of organisms in an area into which they have come by dispersal or migration.
- The concept of mimicry was first given by H.W. Bates in 1862.
- **Probiosis.** Opposite of antibiosis, as stimulating growth of useful intestinal flora.
- **Parasitoids.** Organisms which live as parasites in larval stage but become free living later on, *e.g.*, *Trichogramma*. Parasitoids are used to control crop pests.
- **Brood Parasite (Nest parasite).** Koel (*Eudynamys*) places her eggs in the nest of Crow for incubation and rearing.
- **Sex Parasite.** An Angler Fish (*Photocorynus*) male lives as a small parasite over the head of the female. In *Bonellia* the male is an internal parasite while in *Schistosoma* male lives in gynecophoral canal of the female.
- **Sacculina.** Parasitic barnacle where all adult organs degenerate and animal becomes converted into a mycelium of hyphae. It parasitises crabs.
- **Parasitic Castration.** A male crab parasitised by *Sacculina* develops some female characters while a parasitised female shows degeneration of its ovary.
- **Instant Pathogens.** Newly developed pathogens are more damaging as the hosts have not yet developed adaptations to negative interactions, *e.g.*, SARS.
- Ecological successions on dry habitat, bare rock, sandy soils and aquatic habitat are called **xerosere**, **lithosere**, **psammosere** and **hydrosere** respectively.
- **Antibiosis.** An association of two organisms which is harmful to one of them.
- **Biotope.** A clearly demarcated unit of environment showing uniformity of principal habitat conditions is known as a **biotope**. A sand desert, a sandy or rocky beach, a marshy land or a unit of ocean are examples of biotopes.
- The first scientific account of mimicry was given by the English naturalist **Henry Bates** in 1862 while working on Brazilian butterflies. The Batesian mimicry is named after his name. A German naturalist **Fritz Muller** (1821- 1897) described Mullerian mimicry.
- **Oxylophytes (Oxyphytes).** Plants growing in acidic soils.

- **Eremophytes.** Desert plants, found in deserts and steppes.
- **Chersophytes.** Plants growing in shallow soils or waste land.
- **Psychrophytes.** Plants growing in cold soils.
- **Chasmophytes (Chasmaphils).** Plants growing in rock crevices.
- **Chasmochomophyte.** A plant growing on detritis present in rock crevices.
- **Helophyte.** A marsh plant.
- **Gloger Rule.** Some insects, birds and mammals in warm humid climates bear darker pigment than the races of same species present in cool and dry climates. This phenomenon is known as Gloger rule.
- **Thermophiles.** There are microbes (Archaeobacteria) that live in hot springs and deep sea hydrothermal outlets where temperatures far exceed 100°C.

NCERT TEXT BOOK QUESTIONS WITH ANSWERS

1. How is diapause different from hibernation ?
✓ Refer to differences given in text.
2. If a marine fish is placed in a fresh water aquarium, will the fish be able to survive ? Why or why not?
✓ The marine fish cannot survive in fresh water because of (i) Its water drinking habit. (ii) Endosmosis or entry of water into its body due to osmosis. (iii) Now absorption of salt from water.
3. Define phenotypic adaptation. Give one example.
✓ Phenotypic adaptation is nongenetic changes in physical and physiological characteristics of an individual which are formed in response to specific changes in the environment so as to develop perfect harmony with it.
Example. Relief from mountain sickness after staying for sometime at high altitude.
4. Most living organisms cannot survive at temperature above 45° C. How are some microbes able to live in habitats with temperature exceeding 100°C ?
✓ At temperature, above 45°C, enzymes get denatured, protoplasm gets precipitated and the organism dies. However, microorganisms of hot springs and vents (mouths of sea bed volcanoes) are able to survive at the high temperature due to (i) occurrence of branched chain lipids in their cell membrane that reduce fluidity of cell membranes, (ii) having minimum amount of free water in their cell that provides resistance to high temperature.
5. List the attributes that population but not the individuals possess.
✓ Natalty, mortality, population density, population growth, population dispersal, sex ratio, Age distribution.
6. If a population growing exponentially doubles in size in 3 years, what is the intrinsic rate of increase (r) of the population ?
✓ $t = \log^2/r$ or $r = \log^2/t = 0.7931/3 = 0.264$ or 26.44%
That is, the intrinsic rate of increase of this population will be towards maximum.
7. Name important defence mechanisms in plants against herbivory.
✓ Plants show a number of defence mechanisms against herbivory like (i) presence of thorns, spines, prickles and bristles, (ii) stinging hairs, (iii) hairy coating, (iv) harbouring ants e.g., *Acacia*, (v) sticky glandular hairs e.g., *Gnaphalium*, (v) chemicals like latex, alkaloids and tannins, which have bitter taste and offensive smell, silica and poisonous cardiac glycosides which herbivorous animals do not like.
8. An orchid plant is growing on the branch of mango tree. How do you describe this interaction between the orchid and the mango tree ?
✓ The interaction between the two is called as **commensalism**. Here the orchid is benefitted but the mango tree is not harmed.
9. What is the ecological principle behind the biological control method of managing with pest insects ?
✓ The biological principle involved in biological control method of managing pest insects is checking their population through predators and parasites.
10. Distinguish between the following : (a) Hibernation and aestivation. (b) Ectotherms and endotherms.
✓ Refer to the text.

11. Write a short note on : (a) Adaptations of desert plants and animals
 (b) Adaptations of plants to water scarcity
 (c) Behavioural adaptations in animals
 (d) Importance of light to plants.
 (e) Effect of temperature or water scarcity on the adaptations of animals.
 ✓ (1) **Desert Plants.** (a) Ephemerals grow during rain only, (b) Roots/stem/leaves develop succulence by storing water with the help of latex or mucilage e.g., *Agave*, *Opuntia*, *Bryophyllum*, *Aloe*, (c) Scootactive stomata in CAM plants where stomata remain closed during day, (d) Leaves develop spines or reduce their surface area and develop thick cuticle to reduce transpiration. (e) The OP of cell becomes high to withstand dehydration, (f) Chaperonins are heat shock proteins found in plants of high temperature.
Desert Animals. Burrowing animals in hot areas, water requirement little, Nasal counter current mechanism to prevent loss of water in breathing e.g., kangaroo rat, concentrated urine to conserve water and solid faeces in desert rats, camel etc.
 (b) Same as above in plants
 (c) Migration, camouflage, mimicry, hibernation, aestivation and echolocation.
 (d) Light affects plants through its quality, intensity and duration. Duration of light affects phenology, photosynthesis, growth, reproduction, flowering. Quality of light influences flowering, seed germination and movements. Photosynthesis, growth and reproduction in plants are most effected by light. Photosynthesis is maximum in blue and red light. It is minimum in green. Rate of photosynthesis is maximum in tropics because tropics receive more light than temperate regions.
 (e) Animals of arid areas reduce water loss to minimum e.g., *Kangaroo rat* feeds on dry seed. It seldom drinks water. The requirement of water is met by food and metabolic water. Water loss is checked by living in burrows during the day, nasal counter – current, concentration of urine and solid faeces. **Camel** does not sweat upto body temperature of 50°C. Its nostril size is reduced in dry sandy environment. Nasal counter–current system reduces loss of moisture during exhalation. Camel stops producing urine when water is not available and can remain without water for many days. It meets out its requirement by using metabolic water obtained in oxidation of fats. Animals protect from excessive cold by deposition of fats, thick fur, hibernation. Freeze tolerant animals develop ice nucleating proteins— Freeze avoiding animals develop antifreeze solutes and proteins.
12. List the various abiotic environmental factors.
 ✓ Temperature, light, water, wind, humidity, precipitation (atmospheric factors), slope, altitude, valley, plain (topographic factors), soil type, soil pH, soil aeration and hydration, minerals (edaphic factors).
13. Give an example for (i) ectothermic animal, (ii) endothermic animal, (iii) an organism of benthic zone.
 ✓ Fish, Lizard, Frog. (ii) Horse, Monkey, Man, (iii) Corals, Sponges, Starfish.
14. With the help of suitable diagram, describe the logistic population growth curve.
 ✓ Refer to the text.
15. Select the statement which best explains parasitism. (a) One organism is benefited (b) Both organisms are benefited (c) One organism is benefited, other is not affected (d) One organism is benefited, other is affected.
 ✓ (d)
16. List any three important characteristics of a population and explain.
 ✓ **Population Size** (Population Density). Refer to the text. (ii) **Population Growth.** Refer to the text. (iii) **Age Distribution.** Refer to the text.

TEXT QUESTIONS

One Mark Questions

- Define benthic zone.
 ✓ It is the bottom zone, which has darkness but in shallow waters.
- Define the term ecological factor.
 ✓ Any constituent or condition of the environment which affects directly or indirectly the form and functioning of the organisms in any specific manner is called ecological factor.
- What is flag tree ?
 ✓ It is tree which resembles a flag pole due to absence of branches on the windward side and presence of branches only on the leeward side.

4. How some of aphids and other pests are kept under check in nature ?
✓ Aphids and other pests are kept under check by beetles and other insects, the latter by birds and so on.
5. What is biome ?
✓ A major terrestrial biotic community characterised by distinctive life form, e.g., temperate deciduous forest, grassland etc.
6. What is meant by crude death rate ?
✓ The number of deaths per year for each one thousand individuals in a population.
7. What is detritivore ?
✓ An organism that lives on dead organic material.
8. What is homeostasis ?
✓ The maintenance of equilibrium in an organism or biological system.
9. What is meant by leaching ?
✓ The removal or downward movement by water of soluble chemicals from soil or other materials.
10. What is taiga ?
✓ The northern boreal forest zone, broad band of coniferous forest, south of arctic tundra.
11. Define stenohaline.
✓ The organisms which can tolerate only to a narrow range of salinities are called stenohaline.
12. Which one of the two, stenothermal or eurythermals, show wide range of distribution on earth and why?
(CBSE 2008)
13. Name the type of interaction seen between whale and barnacles growing on its back. (CBSE 2009)
✓ Commensalism.
14. If a marine fish is placed in fresh water aquarium, will the fish be able to survive? Why or why not ?
✓ No, the fish will die due to endosmosis and drinking habit.
15. If 8 individuals in a laboratory population of 80 fruitflies died in a week, then what would be the death rate for population for that said period.
(CBSE 2010)
16. In a pond there were 20 *Hydrilla* plants. Through reproduction 10 new *Hydrilla* plants were added in a year. Calculate the birth rate of the population.
(CBSE 2010)
17. In a pond there were 200 frogs. 40 more were born in a year. Calculate the birth rate of the population.
(CBSE 2010)
18. Pollinating species of wasps show mutualism with specific fig plants. Mention the benefits the female wasps derive from the fig trees from such an interaction.
(CBSE 2011)
19. Why are green plants not found beyond a certain depth in the ocean?
(CBSE 2011)
20. Name the interaction between a whale and the barnacles growing on its back.
(CBSE 2012)
21. Why are green algae not likely to be found in the deepest strata of the ocean?
(CBSE 2013)
22. Write the basis on which an organism occupies a space in its community/natural surroundings.
(CBSE 2013)
23. How is stratification represented in a forest ecosystem?
(CBSE 2014)
24. Give an example of an organism that enters diapause and why?
(CBSE 2014)
25. State Gause's competitive exclusion principle.
(CBSE 2014)

Two Mark Questions (With Sample Answers)

1. Define population and community.
✓ **Population.** A population is a unit of biotic community made up of near permanent group of interbreeding individuals of a species found in a geographical area or space at a particular time.
Community. It is a grouping of different but independent and interacting populations of different species which live in a given locality, e.g., pond community.
2. Distinguish the following : Ectoparasites and Endoparasites.
✓ The parasites which live on the body surface of the host are called **ectoparasites**, e.g., Lice, Bed-bug.
The parasites which live inside the body of the host are called **endoparasites**, e.g., Malarial parasite, *Ascaris*.
3. What are the main functions of water vapours present in the atmosphere ?
✓ (i) They are components of hydrological cycle. (ii) They help in keeping earth warm by intercepting

- infra-red rays passing into space. (iii) Water vapours pick up gaseous nutrients and pollutants and bring them down as wet precipitation.
4. Why cannot a population live alone by itself in nature ?
✓ No population can live alone in nature. It is dependent on other populations for various requirements. Animals get food, shelter and oxygen from plants. Plants depend upon animals for carbon dioxide, pollination, food and ploughing of soil etc.
 5. Clown fish lives among the tentacles of Sea Anemone. What is this interaction between them and why? (CBSE 2008)
 6. Egrets are often seen along with grazing cattle. How do you refer this interaction ? Give a reason for this association. (CBSE 2009)
 7. (a) What is "r" in the population equation given below $\frac{dN}{dt} = rN$.
(b) How does increase and decrease in the value of "r" affect the population size. (CBSE 2009)
 8. Differentiate between the following interspecific interactions in a population (i) Mutualism and competition (ii) Commensalism and amensalism. (CBSE 2010)
 9. Explain the response of all communities to environment over time. (CBSE 2011)
 10. Explain brood parasitism with the help of an example. (CBSE 2012)
 11. Explain why very small animals are rarely found in polar region. (CBSE 2013)
 12. Construct an age pyramid which reflects a stable growth status of human population. (CBSE 2014)
 13. Describe the mutual relationship between fig tree and wasp and comment on the phenomenon that operates in their relationship. (CBSE 2014)
 14. Construct an age pyramid which reflects an expanding growth status of human population. (CBSE 2014)
 15. What is mutualism ? Mention any two examples where the organisms involved are commercially exploited in agriculture. (CBSE 2015)
 16. Many fresh water animals cannot survive in marine environment. Explain. (CBSE 2015)
 17. When you go far a trek/trip to any high altitude places, you are advised to take it easy and rest for the first two days. Comment giving reasons. (CBSE 2015)
 18. How does a desert plant adapt to the dry, warmer environmental conditions? (CBSE 2015)
 19. Why the plants that inhabit a desert are not found in a mangrove? Give reasons. (CBSE 2016)
 20. Plants that inhabit a rain forest are not found in a wetland. (CBSE 2016)

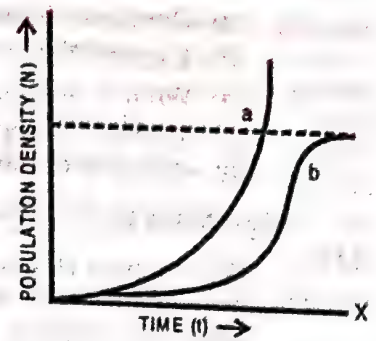
Three Mark Questions

1. How do organisms like fungi, zooplankton and bears overcome temporary short lived climatic stressful conditions? Explain. (CBSE 2010)
2. Water is very essential for life. Write any three features both for plants and animals which enable them to survive in water scarce environment. (CBSE 2011)
3. How do organisms cope with stressful external environmental conditions which are localised or of short duration. (CBSE 2011)
4. Name the type of interaction seen in each of the following examples. (i) *Ascaris* worm living in the intestine of humans. (ii) Wasp pollinating fig inflorescence. (iii) Clown Fish living among the tentacles of Sea Anemone. (iv) Mycorrhizae living on the roots of higher plants. (v) Orchid growing on a branch of a Mango tree. (vi) Disappearance of smaller barnacles when *Balanus* dominated in the coast of Scotland. (CBSE 2011)
5. (a) List any three ways of measuring population density of a habitat.
(b) Mention the essential information that can be obtained by studying the population density of an organism. (CBSE 2012)
6. Explain mutualism with the help of any two examples. How is it different from commensalism? (CBSE 2013)
7. (a) Write the importance of measuring the size of a population in a habitat or an ecosystem.
(b) Explain with the help of an example how the percentage cover is a more meaningful measure of population size than mere numbers. (CBSE 2013)
8. (a) Explain "birth rate" / "death rate" in a population by taking a suitable example. (CBSE 2013)
(b) Write the other two characteristics which only a population shows but an individual cannot. (CBSE 2013)
9. Study the graph and answer the questions. (a) Write the status of food and space in curves a and b.

(b) In the absence of predators which one of the two curves would appropriately depict the prey population. (c) Time has been shown on X-axis and there is a parallel dotted line above it. Give the significance of this dotted line.

(CBSE 2014)

10. (a) State how the constant internal environment is beneficial to organisms. (b) Explain the two alternatives by which organisms can overcome stressful external conditions. (CBSE 2014)
11. How do snails, seeds, bears, zooplankton, fungi and bacteria adapt to conditions unfavourable for their survival? (CBSE 2015)
12. Explain co-evolution with reference to parasites and their hosts. Mention any four special adaptive features evolved in parasites for their parasitic mode of life. (CBSE 2015)
13. Differentiate between mutualism, parasitism and commensalism. Provide one example for each of them. (CBSE 2015)
14. Differentiate between parasitism and competition, giving one example of each. State the common characteristics they share. (CBSE 2015)
15. During a school trip to 'Rohtang Pass', one of your classmates suddenly developed 'altitude sickness'. But she recovered after some time.
 - (a) Mention one symptom to diagnose sickness (b) What caused the sickness? (c) How could she recover by herself after some time. (CBSE 2016)
16. In certain seasons we sweat profusely while in some other season we shiver. Explain. (CBSE 2016)
17. Explain with the help of suitable examples, the three different ways by which organisms overcome their stressful conditions lasting for short duration. (CBSE 2016)
18. Name and explain the type of interaction that exists in mycorrhizae and between cattle egret and cattle. (CBSE 2016)
19. Predation is usually referred to as a detrimental association. State any three positive roles that a predator plays in an ecosystem. (CBSE 2016)
20. Explain parasitism and co-evolution with the help of one example of each. (CBSE 2016)
21. (a) "Organisms may be conformers or regulators. Explain this statement and give one example of each. (b) Why are there more conformers than regulators in the animal world? (CBSE 2017)
22. Different animals respond to changes in their surroundings in different ways. Taking one example each, explain "some animals undergo aestivation while some others hibernation". How do fungi respond to adverse climatic conditions? (CBSE 2017)
23. How do Kangaroo rats and desert plants adapt themselves to survive in their extreme habitat? Explain. (CBSE 2017)



Five Mark Questions

1. Draw and explain a logistic curve for a population of density (N) at time (t) whose intrinsic rate of natural increase is (r) and carrying capacity (k). (CBSE 2010)
2. (a) Explain giving reasons why the tourists visiting Rohtang Pass or Mansarovar are advised to resume normal 'active life' after a few days of reaching there. (b) It is impossible to find small animals in the polar regions. Give reasons. (CBSE 2012)
3. (a) List the different attributes that a population has and not an individual organism. (b) What is population density? Explain any three different ways the population density can be measured with the help of an example each. (CBSE 2015)
4. "Analysis of age pyramids for human population can provide important inputs for long term planning strategies." Explain. (CBSE 2015)
5. (a) Represent diagrammatically three kinds of age pyramids for human populations. (b) How does an age pyramid for human population at given point of time helps the policy makers in planning for future. (CBSE 2016)
6. (a) Name the two growth models that represent population growth and draw the respective growth curves they represent. (b) State the basis for the difference in the shape of these curves. (c) Which one of the curves represents the human population growth at present? Do you think such a curve is sustainable? Give reason in support of your answer. (CBSE 2016)

7. (a) Compare, giving reasons, the J-shaped and S-shaped models of population growth of a species. (CBSE 2017)
- (b) Explain "fitness of a species" as mentioned by Darwin.
8. (a) What is an age pyramid ?
- (b) Name three representative kinds of age pyramids for human population and list the characteristics for each one of them. (CBSE 2017)

Value Based Question

1. On reaching Rohtang pass near Manali, Aryan suffered a bout of breathlessness, nausea, vomiting, palpitation, fatigue and headache. Many of his classmates also fell sick like him. The teacher immediately asked the students to take rest. The attendant was told to provide them coffee. After about one hour the distress symptoms disappeared. What is the rationale behind this?
 ✓ Rohtang pass is at a height of more than 3500 metres. The atmospheric pressure is lower. The oxygen content of the atmosphere is also less. As the body is unable to get enough oxygen, the symptoms of fatigue, nausea and headache appear. This is called **altitude sickness**. The symptoms begin to disappear after some time due to increased formation of erythrocytes, formation of 2, 3-biphosphoglyceric acid and higher rate of breathing. The required oxygen becomes available to the body.

The change in functioning of oxygen transport system is physiological or phenotypic adaptation. It allows human beings (and animals) to adjust themselves to the changes in environment. It also helps in developing excellence in various fields through sincere efforts.

2. What are desert adaptations of animals? What value is learnt from them?
 ✓ Desert animals are able to survive aridity and temperature fluctuations by conserving water use, reducing water loss, passing hot period in cool environment and cool period in warm place. Many desert animals even check the loss of water in exhaled air, e.g., Kangaroo Rat, Camel. Human beings can also do likewise. They can conserve water resources by minimising wastage, using only that much water which is essentially required. Similarly, they can conserve use of electricity/energy by wearing warm clothes during winter (instead of using heaters) and passing hot period of summer in cool places fitted with fans instead of air conditioners.
3. What is Gause's principle of competitive exclusion and competitive release. How would they help you to plant your career?
 ✓ Principle of competitive exclusion of Gause (1934) states that each niche supports only one species. If there are two species having similar functional status, only the superior will remain in the niche while the other is excluded. However, if the niche is large, it may accommodate two or more species. Of course the superior species will dominate the niche while the less efficient will remain fewer in number. If the superior species has small population, the lesser efficient species can increase its number. The phenomenon is called competitive release.

Principle of competitive exclusion is related in human society to such positions which are occupied by single persons, e.g., captain of a team, office incharge, top scorer in the class. If you want to be topper, choose your field carefully where you can specialise and become superior to others. However, in those fields whose niches are large to accommodate several persons (e.g., intake of engineers in one year), a large number of persons would be selected as there is competitive release. However, the number is always limited. Here, again one should specialise in a field where one can reach the number to be selected.

Multiple Choice Questions

- (1) One species is harmed whereas the other is unaffected. The interaction is
 (a) Amensalism (b) Commensalism (c) Parasitism (d) Predation. (HP PMT 2010)
- (2) Which one is appropriately defined ? (a) Host is an organism which provides food to another organism
 (b) Amensalism is a relationship in which one species is benefitted while the other is unaffected
 (c) Predator is an organism that catches and kills other organism for food (d) parasite is an organism that always lives inside the body of the organism and may kill it. (CBSE 2010)
- (3) Consider the following four conditions (i – iv) and select correct pair about desert lizards. (i) Burrowing in soil to escape high temperature. (ii) Losing heat rapidly from the body during high temperature.
 (iii) Bask in sun when temperature is low. (iv) Insulating body due to thick fatty dermis. (a) i, iv (b) i, ii (c) iii, iv (d) i, iii (CBSE 2011)
- (4) Consider the following statements (i–iv) each having one or two blanks. (i) Bears go into (1) during winter to (2) cold weather. (ii) A conical pyramid with a broad base represents (3) human population.

- (iii) A wasp pollinating a fig flower is an example of (4). (iv) An area with high level of species richness is known as (5). (a) (3)—expanding, (4)—commensalism, (5)—biodiversity park (b) (1)—hibernation, (2)—escape, (3)—expanding, (5)—hotspot (c) (3)—stable, (4)—commensalism, (5)—marsh (d) (1)—aestivation, (2)—escape, (3)—stable, (4)—mutualism. (CBSE Mains 2011)
- (5) *Cuscuta* is an example of (a) Endoparasitism (b) Predation (c) Ectoparasitism (d) Brood parasitism. (CBSE Mains 2012)
- (6) A sedentary sea anemone gets attached to the shell lining of hermit crab. The association is (a) Amensalism (b) Ectoparasitism (c) Symbiosis (d) Commensalism. (NEET 2013)
- (7) A biologist studied the population of rats in a barn. He found the average natality was 250, average mortality 240, immigration 20 and emigration 30. The net increase in population is (a) Zero (b) 10 (c) 15 (d) 05. (NEET 2013)
- (8) The removal of keystone species will affect (a) producers (b) decomposers (c) ecosystem (d) consumers. (WB 2014)
- (9) Find the incorrect match (i) Crab — *Sacculina* — Interaction + + (ii) Human being — Mosquito — Interaction - + (iii) Sea anemone — Hermit Crab — Interaction + 0 (a) (i) only (b) (ii) and (iii) (c) (iii) and (i) (d) (ii) only. (MHT CET 2014)
- (10) Plant species having a wide range of genetic distribution evolve into local population known as (a) ecotype (b) population (c) ecosystem (d) biome. (JK CET 2015)
- (11) To which of the following interactions both partners are adversely effected (a) competition (b) predation (c) parasitism (d) mutation. (CBSE 2015)
- (12) It is much easier for a small animal to run uptill than for a large animal because (a) the efficiency of muscles in large animals is less than in small animals (b) it is easier to carry small body weight (c) smaller animals have a higher metabolic rate (d) small animals have a lower O_2 requirement. (NEET-I 2016)
- (13) The principle of competitive exclusion was enunciated by (a) Verhulst and Pearl (b) C. Darwin (c) G.F. Gause (d) MacArthur. (NEET-II 2016)
- (14) Asymptote in a logistic growth curve is obtained when (a) value of 'r' approaches zero (b) $K = N$ (c) $K > N$ (d) $K < N$. (NEET 2017)
- (15) Mycorrhizae are the example of (a) Fungistasis (b) Amensalism (c) Antibiosis (d) Mutualism. (NEET 2017)

Assertion Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—

- (a) If both A and R are true and R is the correct explanation of A
 (b) If both A and R are true and R is not the correct explanation of A
 (c) If A is true but R is false. (d) If both A and R are false.

- Assertion.** Biotic potential is realised only when the environmental conditions are limiting.
Reason. Under such conditions only, the population size can increase at the maximum rate.
 A B C D
- Assertion.** Distribution of age group is said to influence the population growth.
Reason. Population growth is a measure of increase in population over a period of time.
 A B C D
- Assertion.** The relationship between sucker fish and shark is considered to be an example of parasitism.
Reason. Sucker fish gets food and shelter from shark and also alters the growth of shark.
 A B C D
- Assertion.** Predation and parasitism are considered to be negative interactions.
Reason. Parasites and predators limit the population of their host species.
 A B C D
- Assertion.** Generally the intraspecific competition is more intense than interspecific competition.
Reason. Intraspecific competition occurs when the resources are in short supply.
 A B C D
- Assertion.** Generally the population of predator is small.

Reason. Predator checks the population of prey.

A B C D

7. **Assertion.** Plasmodium is an endoparasite.

Reason. Female mosquito is an example of temporary parasite.

A B C D

8. **Assertion.** *Cuscuta* is an example of holoparasite.

Reason. It does not depend on other plants for nutrition requirement.

A B C D

9. **Assertion.** *E. coli* lives inside the human body.

Reason. It is an example of endoparasite.

A B C D

10. **Assertion.** Cold blooded organisms show hibernation or aestivation.

Reason. Extremes of temperature cause inactivity of organisms.

A B C D

11. **Assertion.** People living at high altitudes have higher lung capacity and more red blood corpuscles.

Reason. Hilly persons lead a strenuous life style.

A B C D

12. **Assertion.** Cold blooded animals have no fat layer.

Reason. Cold blooded animals use their fat for metabolic processes during hibernation.

A B C D

13. **Assertion.** Most marine animals find it difficult to live in fresh water and *vice versa*.

Reason. Some animals can tolerate a narrow salinity range while others can bear a wide salinity range.

A B C D

(AIIMS 2012)

14. **Assertion.** Frog can change colour according to its surroundings.

Reason. It is mimicry to capture prey.

A B C D

(AIIMS 2012)

15. **Assertion.** Interspecific competition is the only potent force in organic evolution.

Reason. Unexceptionally two closely related species competing for the same resources cannot coexist indefinitely.

A B C D

(AIIMS 2014)

16. **Assertion.** Presence of pneumatophores in a special adaptation of hydrophytes.

Reason. Pneumatophores are positively geotrophic shoots that have lenticels and help in gaseous exchange.

A B C D

(AIIMS 2016)

ANSWERS

Multiple Choice Questions

(1) —a (2) —c (3) —d (4) —b (5) —c (6) —d (7) —a (8) —c (9) —a (10) —a
(11) —a (12) —c (13) —c (14) —b (15) —d

Assertion Type Questions

1. —(D) 2. —(D) 3. —(C) 4. —(A) 5. —(B) 6. —(B) 7. —(B) 8. —(C) 9. —(A) 10. —(A)
11. —(B) 12. —(A) 13. —(A) 14. —(C) 15. —(D) 16. —(D)

The Ecosystem

Ecosystem is a self regulated and self sustaining structural and functional unit of nature (biosphere) consisting of a community of living beings and its physical environment, both interacting and exchanging materials between them. The area of an ecosystem has uniform environmental conditions. It is called **biotope** (Gk. *bios*— life, *topes*— place). The term 'ecosystem' was introduced by **Tansley** in 1935.

Ecosystems are divisible into two categories, **terrestrial** or land ecosystems (e.g., forests, grasslands, deserts, garden) and **aquatic** or water ecosystems (e.g., fresh water ponds, lakes, streams, estuaries, sea). A **natural ecosystem** is one which develops in nature without human support or interference, e.g., forest, marine ecosystem. An **anthropogenic**, artificial or **man-made ecosystem** is the one which is created and maintained by human beings, e.g., agriculture, garden, aquarium, spacecraft. At most of the places some interference from human beings can be observed, e.g., tree plantation, dam construction. Agriculture or agroecosystem is the largest man-made ecosystem.

Depending upon the size, ecosystem can be small (e.g., edge of a pond, a drop of pond water) or large (e.g., ocean). A small ecosystem is called **microecosystem** (e.g., pond). A very small ecosystem is called **nannoecosystem**, e.g., log of wood, aquarium, kitchen garden. Ocean is a **megaecosystem** while a forest is **mesoecosystem**. Biosphere represents the **global ecosystem**. It is a composite of all local ecosystems present on earth.

Ecosystem is an **open system**. It receives **input** in the form of solar energy and matter (inorganic nutrients). It results in **productivity** or synthesis of organic food. Food with its contained energy passes through various components of ecosystem. Each component as well as the whole ecosystem gives out energy as well as waste matter. It is called **output**. While matter circulates in the ecosystem, energy is lost. Therefore, a regular input of energy is essential for maintaining any ecosystem.

Homeostasis of the Ecosystem or Biological Equilibrium ("Balance of Nature")

An ecosystem maintains a functional balance or relatively stable state of equilibrium amongst its various components. The phenomenon is called **homeostasis** or **balance of nature**. It is not static but fluctuates within certain limits. Homeostasis or balance of nature is maintained through a number of controls (= limitations = cybernetics). The important ones are : (i) **Carrying capacity** of the environment. (ii) Capacity of the ecosystem for **recycling of wastes**. (iii) **Self regulation** through the effect of density on reproductive potential, e.g., flour beetle, tree toad. (iv) **Feed back system**. In feed back system, one living component of the ecosystem controls the population

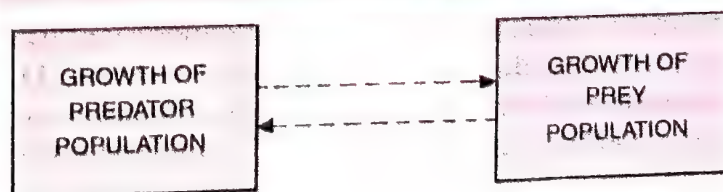


Fig. 14.1. Feedback system for controlling populations of prey and predator.

of another living component. Feedback system is of two types, **positive** and **negative**. For example, increase in plant matter would increase the population of herbivorous insects. The latter results in the increase in population of frogs, predator insects and insectivorous birds. This increase in population of different level organisms with increase in population at the lower level of food chain is called **positive feed back**. The increased population of insectivorous animals would, however, soon exert a **negative feed back** on the population of herbivorous insects through excessive predation (Fig. 14.1). Thus availability of food is an important factor in maintaining population densities and hence balance of nature.

Organization (Components) of the Ecosystem

An ecosystem is made up of two types of components, **biotic** and **abiotic**.

I. Biotic Components

They constitute all the living members of an ecosystem. The different biotic components are connected through food and a number of other relations. *Food is a group of materials that contain energy and ingredients essential for body building, growth and body functions.* Both matter and energy are transferred in the living world through food. Food is manufactured from inorganic raw materials by autotrophs only. Autotrophs are, therefore, also called **producers**. Other organisms which cannot manufacture their own organic food are called heterotrophs. Heterotrophs are of two main types, **consumers** (herbivores and carnivores) and **decomposers**.

1. **Producers (Autotrophs)**. They are photosynthetic or autotrophic plants which are able to synthesise organic food from inorganic raw materials with the help of solar radiations. The process is called photosynthesis. Energy contained in solar radiations is first changed into chemical form by chlorophyll of photosynthetic plants. This chemical energy is then used in bond building of organic compounds. The energy can be released when the bonds of the organic compounds are broken down as during respiration. Producers are also called **transducers** because they are able to change radiant or light energy into chemical form. Organic compounds synthesised by producers take part in building their bodies as well as release of energy for various body activities.

All other organisms depend upon the producers for their supply of organic compounds or food. Producers also maintain CO_2/O_2 balance of nature. They pick up carbon dioxide from the atmosphere and release oxygen during the process of photosynthesis.

Major producers are algae, bryophytes and vascular plants. Others are photosynthetic bacteria, chemosynthetic bacteria and photosynthetic protists. In terrestrial ecosystems, producers are generally rooted plants. **Phytoplankton** or small photosynthetic drifting organisms are major producers of aquatic ecosystems, especially the deeper ones. Rooted plants occur in shallow waters. They are called **macrophytes**.

2. **Consumers (Heterotrophs)**. They are animals which feed on other organisms or their parts. Consumers ingest their food. They are, therefore, also called **phagotrophs**. Being of larger size as compared to decomposers, they are also called **macro-consumers**. Consumers are differentiated into two broad categories, **herbivores** and **carnivores**. Herbivores obtain their food (and energy) directly from plants. They are called **first order consumers**. Some common herbivores of terrestrial ecosystems are deer, rabbit, mouse, squirrel, grass-hopper, some beetles, goat, cattle, etc. Similar herbivores of the aquatic ecosystem are mostly crustaceans, molluscs and protozoans. Herbivores have been called **key industry animals** by Elton (1927) as they change plant matter into animal matter.

Carnivores ingest or prey upon other animals. The carnivores which feed on herbivores are named as **primary carnivores** or **second order consumers**, e.g., frog, centipede, birds,

fishes, wild cat, jackal, fox, snakes, etc. The animals which feed on primary carnivores are called **secondary carnivores** or **third order consumers**, e.g., owl, peacock, several fishes, tiger, lion, etc. Secondary carnivores may become food of tertiary carnivores and so on. The carnivores, which cannot be preyed upon further, lie at the top of food chain and are termed as top carnivores, e.g., Lion.

3. **Decomposers (Reducers)**. They are saprotrophs which feed on dead bodies of organisms and organic wastes of living organisms. The decomposer organisms secrete digestive enzymes to digest the organic matter externally. The digested form of organic matter is partly absorbed by micro-organisms for their own assimilation. The remaining adds raw materials and minerals back into the substratum. The phenomenon is called **mineralisation**.

Decomposers are also called **reducers** because they are able to remove or degrade the dead bodies of organisms. Because of their small size they are known as **micro-consumers**.

Some workers differentiate two more categories of living beings amongst the biotic components of an ecosystem. They are **detrivores** and **parasites**. Parasites belong to diverse groups, e.g., bacteria, fungi, protozoans, worms, etc. Every type of living being can be attacked by parasites. Detrivores or **scavengers** are animals which feed on dead bodies of other organisms, e.g., termites, carrion beetles. They are helpful in quick disposal of the dead bodies.

II. Abiotic Components

Abiotic component of an ecosystem consists of non-living substances and factors. The important ones are as follows.

1. **Temperature**. Organisms generally live within a narrow range of temperature (5° – 35°C) with the exception of spores, seeds, some prokaryotes and other lowly organised individuals. The latter can be found in hot springs (60° – 90°C) or permafrost (-30° to -50°C). Temperature range varies in different parts of the earth. It has created different life zones— tropical, subtropical, temperate, arctic or alpine. High or low temperature causes inactivity and death of organisms. It is immediate in case of **poikilothermal** (= ectothermal = cold blooded) animals and delayed in case of **homoiothermal** (= endothermal = warm blooded) animals. Therefore, organisms show adaptations to avoid extremes of temperature.

Plants belonging to both hot and cold areas possess adaptations to reduce transpiration and retain water, e.g., tannins, hair, thick covering, mucilage, high solute content, thick leaves. Animals of cold areas possess thick coat of hair, scales, feathers and subcutaneous fat. In warm blooded animals, including humans, pigmentation is little in colder areas, yellow brown to red in arid climates and black in humid hot areas (Gloger's rule).

2. **Light**. It provides solar energy to the ecosystem for heating and photosynthesis. Maximum solar or light energy is available at equator. It decreases towards poles. In a tree more energy is available to upper leaves than the lower ones. Their rate of photosynthesis is accordingly higher.

In a forest, trees have higher productivity than shrubs and herbs growing underneath. Floating hydrophytes have higher photosynthetic rate than the submerged hydrophytes. Besides photosynthesis, light controls morphogenesis (photomorphogenesis). Photoperiods influence leaf fall, appearance of new leaves and flowering in plants. They control migration and breeding in several animals.

3. **Wind**. It controls weather, transpiration, pollination and dissemination of propagules. High speed winds inhibit tree growth and flight animals. Unidirectional wind does not allow growth of branches on the wind-ward side.

4. **Humidity.** It is the amount of water vapours present in the atmosphere. Humidity controls formation of clouds, dew, fog, etc. Epiphytes grow only in humid areas. Evaporation of water from the body of land organisms in transpiration and perspiration is regulated by humidity. Both plants and animals develop modifications for reducing water loss from their body in arid areas.

5. **Precipitation.** It may occur as rainfall, snow, dew, hail, etc. Periodicity and amount of rainfall determines type of forest in an area—evergreen, deciduous, chapparal, grassland, savannah, desert, etc. Animals are also adopted accordingly.

6. **Water.** Land plants meet their water requirements from soil. Land animals obtain the same from pools, lakes, rivers, springs, etc. Plants and animals show modifications according to availability of water in the area and requirement of conserving the obtained water. Plants of dry areas are called **xerophytes**. They develop modifications to increase water absorption, reduce transpiration and at times store absorbed water. Certain animals of the dry areas do not drink water at all, e.g., Kangaroo Rat. They use water from food and its metabolism to run their body machinery. Animals of dry areas often reduce water loss by producing solid faeces and excreting solid urine.

Water is abundant in aquatic habitats. Plants of aquatic habitats are called **hydrophytes**. Hydrophytes possess **aerenchyma** or air storing parenchyma to support themselves in water. Clarity of water, salt content, depth and water waves or speed determine the growth and distribution of plants and animals. In rivers and streams, animals obtain most of their food from organic materials coming from outside the water. In ponds and lakes producers grow in sufficient strength. Organisms found in fresh water have a problem of excess internal water because of endosmosis. Organisms found in ocean or saltish water have a problem of low internal water content due to exosmosis. Some have problem of excreting excess salts obtained from outside. In oceans at a depth of more than 200 m, producers do not occur. Only consumers are found there. Deep sea animals do not possess air sacs. Many of them are luminescent.

Water currents restrict distribution of organisms in streams and intertidal areas of oceans. In streams only attached plants grow. They have dissected or ribbon shaped leaves. Animals found here are either strong swimmers, have attaching organs or live under stones, in burrows, crevices etc. Similarly in intertidal area of ocean attached plants (*Fucus*, *Laminaria*), sessile animals (Sea anemone and limpets), burrowing animals (e.g., *Nereis*, tube worms) or very strong swimmers are met with.

7. **Background.** Most animals have an adaptation to have colour, pattern and general texture similar to that of the background in which they operate. This allows them to camouflage themselves so that they do not become conspicuous to their preys or predators. For example, elephants and rhinos have colour to that of tree trunks and mud. Lions and camels are sand coloured. Praying Mantis, Tree Frog, (*Hyla*) and Grasshopper are green in colour. Jelly-fishes and Sea-cucumbers are glassy. Chameleon is able to change its colour according to the background.

8. **Topography.** It is the surface behaviour of the earth like altitude, slope, exposure, mountain chains, valleys, plains, etc. Topography influences other environmental factors, atmospheric pressure, winds, rainfall, light intensity and light duration, temperature, water currents or wave action. It is also a causal agent for isolation, formation of new species and of flora and fauna because they differ in their humidity, rainfall, light intensity, light duration and temperature regimes. It is because the two faces of the hill receive different amounts

of solar radiations and wind action. Similarly, the centre and edge of a pond possess different depths of water and different wave action. Top side of a rock is exposed to wave action and light while the underside of the rock has little wave action and light. Therefore, different parts of the same area may possess different species of organisms.

9. **Gases.** Nitrogen is present in abundance (4/5th of atmosphere) but is itself chemically inert. It forms useful salts through electrochemical, photochemical and biological fixation. Carbon dioxide concentration of the atmosphere is always a limiting factor for photosynthesis. However, excess of carbon dioxide concentration is harmful to animals as well as climate. Its concentration increases during night but decreases during day. In water it occurs as bicarbonate and carbonate ions. Oxygen concentration is supra-optimal for C_3 plants, optimal for C_4 plants and animals except at high altitudes. In water oxygen concentration determines distribution of organisms. In the middle or intermediate stratum photosynthesis increases oxygen concentration during day but it becomes little during night depending upon population, pollution and decomposition. In deep waters, animals are faced with very low oxygen concentration.

10. **Soil.** It determines vegetation growth and pattern, under-ground flora and fauna through its constitution, origin, temperature range, water retentivity, aeration, minerals, etc. Soil present on the slopes as well as the one which is uncovered are liable to be eroded by water and air respectively.

11. **pH (Hydrogen ion Concentration).** There is very little change in pH in oceans. Terrestrial animals are also not much influenced by pH of the substratum. However, distribution of land plants and soil organisms is determined by pH of soil. Snails and earthworms do not occur in acidic soils. A similar control on distribution is found in fresh water habitats. At acidic pH, *Euglena* and other flagellates are quite abundant. Animals having calcareous shells live in media having neutral or alkaline pH.

12. **Mineral Elements.** A large number of minerals, also called biogenic or biogenetic nutrients, are required by organisms for their proper growth. Deficiency or absence of any one results in abnormal growth which may lead to death. Excess minerals are equally harmful. Abundance of some minerals favour the growth of some tolerant species. Snails occur in soils rich in calcium content. Soils deficient in nitrogen salts often possess nitrogen fixing bacteria and cyanobacteria. Plants having symbiotic relationship with these bacteria also abound in the soils. Carnivorous plants meet their requirement of nitrogen by catching small insects, worms, etc. Salinity of ocean is overcome by many animals through salt secreting glands. Similar glands occur in halophytes or plants growing in saline soils and marshes. Special adaptations are found in animals inhabiting estuaries where there are wide fluctuations in salt content. Areas having very high salt content are usually devoid of much vegetation, e.g., Dead Sea, Great Salt Lake.

Differences between Biotic and Abiotic Components of Ecosystem

Biotic Components	Abiotic Components
<ol style="list-style-type: none"> 1. They represent the living organisms present in an ecosystem. 2. Biotic components include producers, consumers and decomposers. 3. They build up and utilize chemical energy for their functioning. 4. For their body building, they obtain inorganic nutrients and energy from abiotic components. 	<ol style="list-style-type: none"> 1. They represent nonliving structures and factors of the ecosystem. 2. Abiotic components include inorganic nutrients, organic remains and physical factors. 3. They are influenced by physical form of energy as light and heat. 4. They determine the liveability and maintainability of biotic components.

Ecosystem Structure

1. **Species Composition.** It is studied through identification and enumeration of plant and animal species of the ecosystem. Species composition differs from one ecosystem to another depending upon geography, topography and climate. Maximum species composition occurs in tropical rain forests and coral reefs. Minimum occurs in deserts and arctic regions.
2. **Stratification.** It is formation of vertical layers where vegetation is dense, e.g., 5–7 strata in tropical rain forests with emergent tall trees, canopy trees and under-storey trees at the top, shrub layer below the tree layer, and bottom layer of herbs and grass at the ground level. Stratification is absent or rare in deserts.
3. **Trophic Structure.** Each ecosystem has specific food chains and food webs, e.g., grazing food chain in grassland.
4. **Standing Crop.** It is the amount of living biomass or number of living organisms present in a unit area of an ecosystem. Dry weight is preferred over fresh weight because the latter is liable to be influenced by seasonal moisture differences.
5. **Standing State.** It is the amount of inorganic nutrients present any time in the soil/water of ecosystem. It tends to vary from season to season and ecosystem to ecosystem.

Differences between Standing Crop and Standing State

<i>Standing Crop</i>	<i>Standing State</i>
1. Standing crop is amount of biomass present in an ecosystem.	1. Standing state is amount of inorganic nutrients found in an ecosystem.
2. It represents the entire living matter.	2. It represents part of nonliving matter.
3. There is no circulation.	3. It circulates between living and nonliving components of the ecosystem.
4. Continuous synthesis and consumption of biomass are going on.	4. It is being regularly depleted and replenished by the living matter.

Ecosystem Functions

All the components of an ecosystem function as a unit with a number of delicately balanced and controlled processes. Plants withdraw biogenetic nutrients from the soil. Their availability is largely dependent upon decomposition and mineralisation of organic detritus. Animals found in an ecosystem are delicately balanced by the number of herbivores and the degree of herbivory. Four important functional aspects of the ecosystem are (i) Productivity, (ii) Decomposition, (iii) Energy flow and (iv) Nutrient cycling.

A Pond Ecosystem

Pond is a self-sustained ecosystem present in a shallow water body. It has all the structural components which work as a unit and show all the four functional aspects of the ecosystem.

Structure. It has both abiotic and biotic components.

Abiotic components include water, dissolved inorganic and organic substances and soil deposit at the bottom. Solar energy, cycle of temperature, day length and other climatic conditions regulate the functions. **Biotic components** are producers, consumers and decomposers. Producers are autotrophs like phytoplankton, some larger algae, submerged floating and amphibious (towards the edge) plants. Consumers are zooplankton, free swimming and bottom dwelling animals. They are differentiated into herbivores and carnivores.

The important herbivores are zooplankton, larvae, tadpole and some fish. Primary carnivores include Water Scorpions, Water Beetle, Dragonfly larvae, *Hydra* and some fish. Secondary carnivores are larger fish and many water birds. Decomposers include fungi, bacteria and flagellates. They are especially abundant at the bottom.

Functions. A pond performs the functions of any ecosystem as well as the biosphere as a whole. With the help of radiant energy, autotrophs convert the inorganic materials into organic matter. It is **primary productivity**. Autotrophs are consumed by heterotrophs which build up their own organic matter. It is **secondary productivity**. Organic wastes and dead organisms are acted upon by decomposers. Minerals are released in the process. The minerals become available to autotrophs for reuse. There is cycling and recycling of matter. However, energy flow is unidirectional. Solar energy is trapped by autotrophs. A part of it is lost by autotrophs. As organic matter, energy passes to consumers. Every category of consumer dissipates a part of energy. The dissipated energy is lost as heat to the environment.

Productivity

The rate of synthesis of energy containing organic matter or biomass by any trophic level per unit area in unit time is described its productivity. It is measured as weight (e.g., g/m²/yr) or energy (e.g., Kcal/m²/yr). **Production ecology** is the branch of ecology that deals with rate of production of organic matter in different components of an ecosystem. Productivity is of the following types :

Primary Productivity. The amount of energy accumulation in green plants as biomass or organic matter per unit area over a time period through the process of photosynthesis is known as primary productivity. It is of two sub-types.

(a) **Gross Primary Productivity (GPP).** The total organic matter synthesised by the producers in the process of photosynthesis per unit time and area is known as gross primary productivity. It includes the weight of organic matter added in the body of the producers plus the losses suffered by them due to respiration, grazing and other damages.

(b) **Net Primary Productivity (NPP).** It is the weight of the organic matter stored by the producers in a unit area/volume per unit time. Net primary productivity is equal to the rate of organic matter created by photosynthesis minus the rate of respiration and other losses.

$$NPP = GPP - R$$

Differences between Net Primary Productivity and Gross Primary Productivity

Net Primary Productivity	Gross Primary Productivity
<ol style="list-style-type: none"> 1. It is the amount of organic matter stored by producers per unit time and per unit area. 2. Net primary productivity is equal to organic matter synthesized by photosynthesis minus utilization in respiration and other losses. 3. It depends upon gross primary productivity as well as amount of consumption of photosynthates. 	<ol style="list-style-type: none"> 1. It is the amount of organic matter synthesized by producers per unit time and per unit area. 2. Gross primary productivity is equal to rate of increase in body weight of producers plus loss suffered through respiration and damages. 3. It depends upon photosynthetic efficiency of producers, availability of solar energy as well as inorganic nutrients.

Secondary Productivity. The rate of resynthesis of organic matter by the consumers is known as secondary productivity. It depends upon the loss while transferring energy containing organic matter from the previous trophic level plus the consumption due to respiration and predation. Respiration loss is about 20% for autotrophs, 30% for herbivores

and upto 60% in case of carnivores. Therefore, net productivity decreases with each trophic level.

Yield of an ecosystem depends upon the trophic level exploited by man. It is usually T_2 or second trophic level (herbivores) which is exploited on land for protein while in ocean the trophic levels harvested by man are T_3 , T_4 or T_5 .

Differences between Primary Productivity and Secondary Productivity

Primary Productivity	Secondary Productivity
1. It is rate of synthesis of organic matter by producers.	1. It is rate of synthesis of organic matter by consumers.
2. It is comparatively quite high.	2. It is small and decreases with rise of trophic level.
3. It is due to synthesis of fresh organic matter from inorganic raw materials.	3. It is due to synthesis of organic matter from organic matter.

Productivity Levels (Fig. 14.2)

They depend upon plant species of the area, their photosynthetic capacity, availability of nutrients, solar radiations, precipitation, soil type and a number of other environmental factors. Previously 90% of the productivity of the whole biosphere was believed to be due to oceans. New estimates are that they contribute only 32% of the total (55 billion tons out of 170 billion tons).

1. High Productivity Ecosystems.

The net productivity is about $2-4 \text{ kg/m}^2/\text{yr}$ ($20-40 \text{ t/ha/yr}$). Depending upon the types of producers, the daily productivity ranges from $6-20 \text{ gm/m}^2$. The ecosystems occur in tropical forests, flood plains, coral reefs, areas of upwelling, sugar cane fields, etc. Maximum productivity occurs in coral reefs, followed by estuaries (area of upwelling) and sugarcane fields.

2. Average Productivity Ecosystems.

The productivity is $1-2 \text{ kg/m}^2/\text{yr}$ ($10-20 \text{ t/ha/yr}$) with a daily output of $3-5 \text{ gm/m}^2$. Common agricultural crops and temperate forests belong to this category.

3. Less Productivity Ecosystems.

The annual productivity is $200-1000 \text{ gm/m}^2$ ($2-10 \text{ t/ha}$) with a daily increment of $0.5-3.0 \text{ gm/m}^2$. Examples are found in grassland ecosystems and savannah.

4. Low Productivity Ecosystems.

The net productivity is less than $200 \text{ gm/m}^2/\text{yr}$ (2 t/ha/yr). It is as low as $.03 \text{ t/ha/yr}$ ($3 \text{ gm/m}^2/\text{yr}$) in certain deserts. The ecosystem is found of water accompanied by high temperature in hot deserts and low temperature in cold deserts. In oceans productivity is limited by light (decreases with depth) and nitrogen.

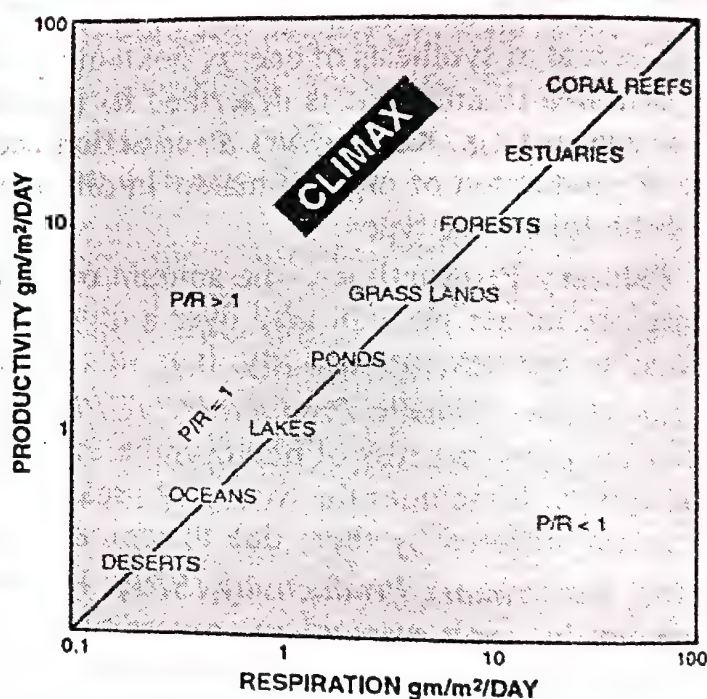


Fig. 14.2. Magnitude of primary production in various ecosystems and climatic regions.

Whittaker (1970) and Lieth (1974, 1975) have compiled data about the net productivity of major ecosystems of the world (Fig. 14.2). According to them the net productivity of the land is about 11.5×10^{10} tons/yr (total land area 149×10^6 km²). The average or mean value is 7.7t/ha/yr (770 gm/m²/yr). The net productivity of the oceans is about 5.5×10^{10} tons/yr (with a total area of 361×10^6 km²) with an average value of 1.55t/ha/year (155 gm/m²/yr). The total annual production comes to about 17.0×10^{10} tons (170 billion tons). The total biomass or standing crop at any time is believed to be 185.5×10^{10} tons in terms of dry matter.

On land the maximum primary production rate is found in tropical rain forests followed by tropical deciduous forests, temperate forests, savannah, temperate grasslands and desert scrub (Table 14.1).

Table 14.1. Geographic Area, Mean Plant Biomass and Net Productivity in Major World Ecosystems

Ecosystem	Area (million km ²)	Plant Biomass t/ha or 1000 kg/10000 m ²	Mean Net Primary Productivity t/ha/yr
Tropical Rain Forests	17	440	20
Tropical Deciduous Forests	08	360	15
Temperate Deciduous Forests	07	300	12
Temperate Coniferous Forests	12	200	08
Savannah	15	40	09
Temperate Grassland	09	20	05
Desert Scrub	18	10	0.7

Cultivated land occupies an area of about 14×10^6 km². Its total annual yield has been estimated to be 1×10^{10} tons (dry). The yield is very high in the tropical areas as compared to cold and dry lands. The reason for the higher yield of crop lands is subsidization of solar powered ecosystem with man-made machines and extra nutrients added by man besides providing protection against pests and parasites. The productivity of all natural habitats gets augmented wherever the solar powered ecosystem is subsidized, e.g., tidal waves in coastal estuaries, wind and rain in tropical rain forests, flowing water in streams, etc. In sea the regions of upwelling occupy only 0.1% of the area off the coasts of Peru, California, Africa, Arabia and Antarctica. They provide about 50% of the fish supply of the world because of continuous sweeping up of water from the bottom which brings nutrients alongwith.

Factors Affecting Primary Productivity

Primary productivity depends upon **light, temperature, water, nutrients** and photosynthetic capacity/efficiency of producers. In tropical regions, primary productivity may be sustained throughout the year, provided adequate water is available in soil. In temperate regions, primary productivity is limited by severity of cold climate and length of snow free growing period.

1. Solar Radiations. Sun light is the ultimate source of energy. Maximum light is available in tropics. Poles receive minimum light. Due to this, photosynthesis is maximum and net primary productivity (NPP) is highest (> 20 t ha⁻¹year⁻¹) in tropics against average (8t ha⁻¹year⁻¹) in temperate forests. In aquatic ecosystems, productivity is less than terrestrial ecosystem. It is limited by light which decreases with increasing water depth. Their productivity is about 55 billion tonnes as compared to 115 billion tonnes of biomass by terrestrial plants.

2. **Temperature.** Temperate forests have lesser productivity (about $8 \text{ t ha}^{-1} \text{ year}^{-1}$) than tropical rain forests ($20 \text{ t ha}^{-1} \text{ year}^{-1}$) due to cold climate that severely limits the PP. Alpine and Arctic zones have very less productivity due to low temperature almost throughout the year.

3. **Moisture.** Rain and humidity increase productivity of the ecosystem. It decreases with water scarcity. Deserts have the lowest primary productivity ($<1 \text{ t ha}^{-1} \text{ year}^{-1}$). Grassland have primary productivity of 5 tonnes per hectare per year as compared to 20 t/ha/year of tropical rain forests.

4. **Nutrients.** Nutrients are essential for growth of producers. Nitrogen is deficient in oceans that limits productivity in marine ecosystems. Desert soils are deficient in nutrients and therefore, are less productive. Estuaries and Coral reefs are highly productive as the nutrient supply is rich.

5. **Photosynthetic Efficiency of Producers.** C_4 plants are more productive than C_3 plants. Sugarcane is most productive crop being efficient in trapping light.

Decomposition

It is physical and chemical breakdown of complex organic remains with the help of organisms called decomposers. In terrestrial ecosystem, upper layer of soil is the main site of decomposition. Organic remains (dead plant parts, animal remains and excretions) are also called **detritus**. It is of two types— **above-ground detritus** (leaf litter, dried plant parts, remains of animals, their droppings and excretions) and **below-ground detritus** (mainly dead roots, also underground dead animals).

Decomposition Processes

Decomposition completely disposes off the whole detritus. It helps in recycling of biogeochemicals and creating space for newer generations of organisms. A number of processes are involved in decomposition. They are grouped into three categories, all of which operate simultaneously. (i) **Fragmentation of Detritus.** Detritivores (e.g., termites, carrion beetles, earthworms) feed on larger pieces. The smaller fragments are left. Pulverisation occurs in the digestive tract of detritivores as a part of detritus comes out undigested. The part digested by detritivores is immobilized. Due to fragmentation, left-over detritus comes to have large surface area. Earthworms are called **farmer's friends** because they help in fragmentation of detritus and loosening of soil. (ii) **Catabolism.** The decomposers (e.g., bacteria, fungi) excrete digestive enzymes over the detritus. It changes insoluble complex organic substances into simple and soluble organic compounds and inorganic substances. A part of the broken down food is taken up by decomposers and immobilised. (iii) **Leaching.** Soluble substances formed during decomposition are subjected to leaching or passage to deeper layers of soil/ground water by percolating water.

Decomposition process gives rise to two products, **humus** and **inorganic nutrients** (= minerals). Processes involved in their formation are called **humification** and **mineralisation** respectively. Humification is the process of formation of humus from detritus or organic remains. Humus is dark coloured amorphous organic matter rich in lignin and cellulose. It is quite resistant to microbial action, a reservoir of nutrients and helpful in maintenance of soil moisture as well as aeration. It is colloidal in nature. Nutrients are released slowly as the humus is slowly decomposed. **Mineralisation** is the release of inorganic substances, both non-mineral (e.g., CO_2 , H_2O) and minerals (e.g., Ca^{2+} , Mg^{2+} , K^+ , NH_4^+) from organic

matter. The process is slow because of trapping in humus and immobilisation in decomposers/detrivores. It prevents their washing out or leaching. Nutrients immobilised in decomposer microbes and detrivores are again exposed to humification and mineralisation after the death of these organisms.

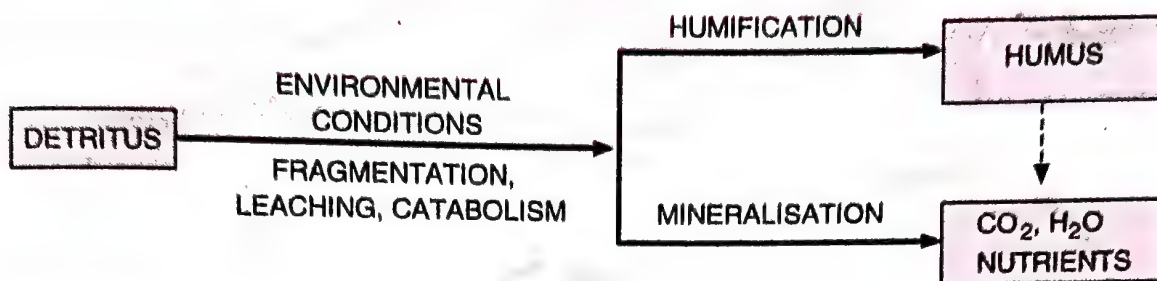


Fig. 14.3. Processes involved in decomposition of detritus.

Differences between Detrivores and Decomposers

<i>Detrivores</i>	<i>Decomposers</i>
<ol style="list-style-type: none"> 1. They are animals which feed on detritus. 2. Detrivores ingest the organic matter. 3. Ecologically they cause pulverization or fragmentation of detritus. Examples. Earthworm, Carrion beetle. 	<ol style="list-style-type: none"> 1. They are micro-organisms which obtain nourishment from organic remains. 2. They decompose the organic matter by secreting digestive enzymes over it. 3. Ecologically they cause humification and mineralisation of organic matter. Examples. <i>Pseudomonas</i>, Slime Moulds.

Factors. Rate of decomposition of detritus depends upon chemical quality of detritus, temperature, soil moisture and soil pH. The last three influence activity of detrivores and decomposer microbes. (i) **Temperature.** A soil temperature of 25°C and more hastens decomposition, taking from a few weeks to a few months for complete mineralisation and humification. Humus also does not persist beyond a couple of months. A low temperature of less than 10°C reduces rate of decomposition. As a result in many temperate forests detritus piles up at the ground level. (ii) **Moisture.** It is essential for decomposition. Decomposition rate is very low in tropical deserts despite presence of favourable temperature. Excessive moisture also impedes decomposition probably due to anaerobiosis. (iii) **pH.** Neutral and slightly alkaline soils are rich in detrivores, earthworms and decomposer microbes. Acidity decreases the number of detrivores and earthworms. Decomposer microbes occur in slightly acidic soils but with the rise in acidity, their number begins to fall. As a result decomposition of detritus is quite slow in acidic soils. (iv) **Composition.** Chitin and lignin are very slow to get decomposed. Cellulose decomposition takes time. Therefore, detritus with small amount of lignin/chitin/cellulose which is rich in nitrogen and water soluble substances (like sugars) decomposes rapidly. (v) **Aerobiosis.** Aerobic conditions are essential for activity of decomposer organisms because decomposition is oxygen requiring process. Anaerobiosis reduces decomposition and causes piling up of detritus.

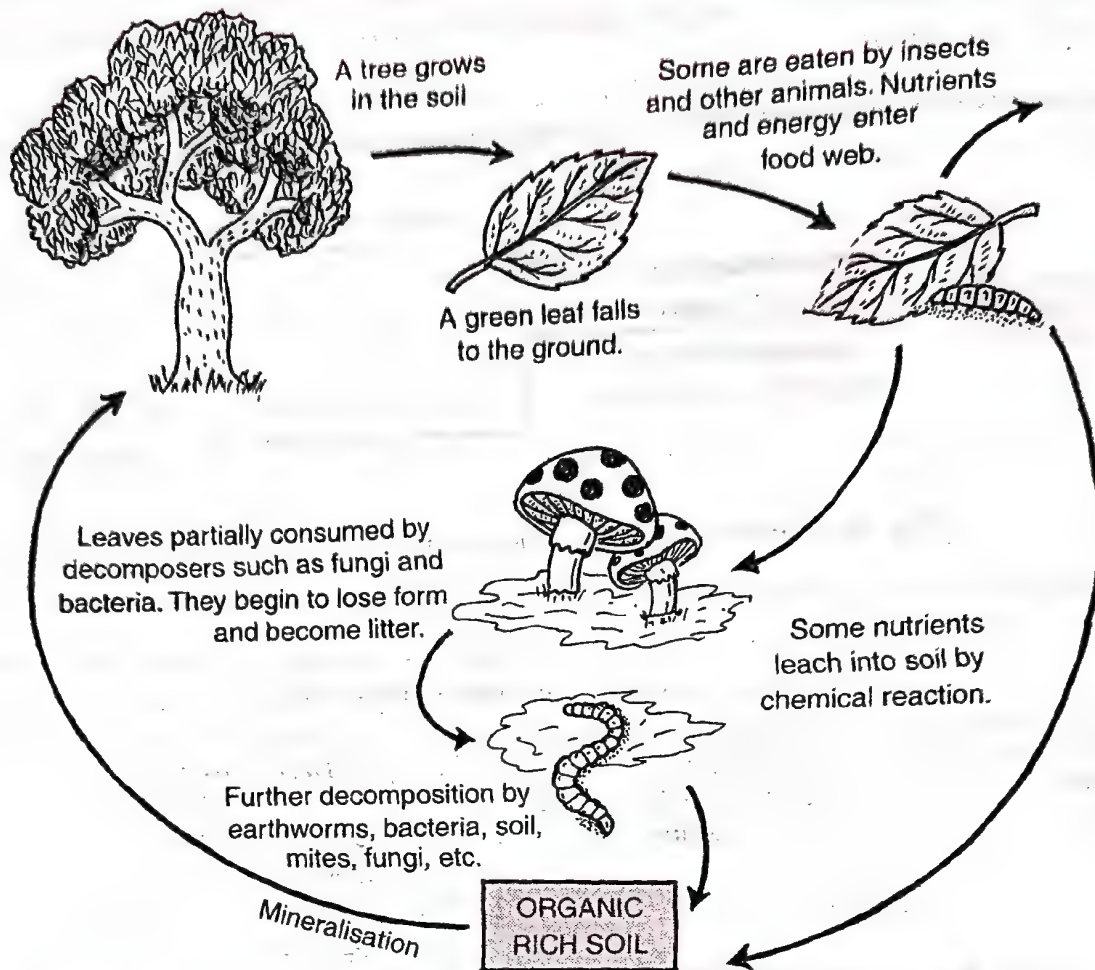


Fig. 14.4. Schematic representation of decomposition cycle in a terrestrial ecosystem.

Differences between Production and Decomposition

<i>Production</i>	<i>Decomposition</i>
<ol style="list-style-type: none"> 1. It is the process of synthesis of organic compounds/biomass from inorganic matter using sunlight by producers (plants). 2. It traps energy. 3. It builds up biomass from inorganic nutrients. 	<ol style="list-style-type: none"> 1. It is the process of breaking down of a substance/waste biomass into its constituent parts by decomposers (bacteria, fungi). 2. It releases energy. 3. It releases inorganic nutrients from the biomass.

Differences between Detritus and Litter

<i>Detritus</i>	<i>Litter</i>
<ol style="list-style-type: none"> 1. It is remains of plants and animals i.e., it is freshly deposited organic matter. 2. It is of two types, above ground and below ground. 	<ol style="list-style-type: none"> 1. Litter is mostly dried fallen plant matter. 2. It is above ground.

Trophic Levels (Figs. 14.5-6)

Trophic level is a step or division of food chain which is characterised by the method of obtaining its food. The number of trophic levels is equal to the number of steps in the food chain. The two fundamental trophic levels are **producers** and **consumers**. A fundamental similarity of all trophic levels is that it uses a part of food in body building while a major part of it is consumed in liberation of energy during respiration.

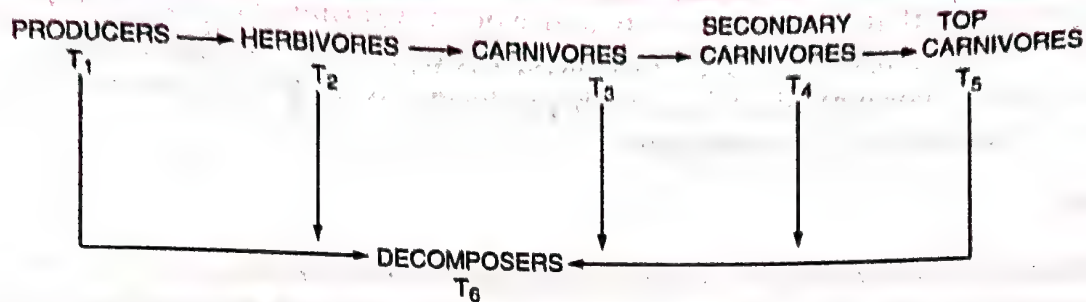


Fig. 14.5. Trophic levels in ecosystem.

Producers belong to first trophic level or T_1 . They are *autotrophic or photosynthetic organisms found in an ecosystem which synthesise organic nutrients from inorganic raw materials with the help of solar radiations not only for themselves but also for heterotrophic organisms or consumers*. Autotrophs or producers possess chlorophyll for this purpose. Chlorophyll converts solar or light energy into chemical form. The chemical energy is stored in the bonds of organic materials.

Consumers are heterotrophic organisms which cannot manufacture their own food. They obtain ready-made organic food from outside sources. Depending upon the mode of obtaining nourishment, heterotrophic organisms are of three main types—herbivores, carnivores and decomposers. **Herbivores** or consumers of first order constitute the second trophic level or T_2 . Consumers of the second order or primary carnivores form third trophic level or T_3 . There may be 2–3 levels of carnivores. The ultimate or top carnivores belong to T_4 or T_5 trophic level. Decomposers form the last or detritus trophic level (e.g., T_6). Parasites do not have any fixed trophic level since they feed on producers, herbivores as well as carnivores of various levels, e.g., aphids, ticks, mites, leeches, mosquitoes.

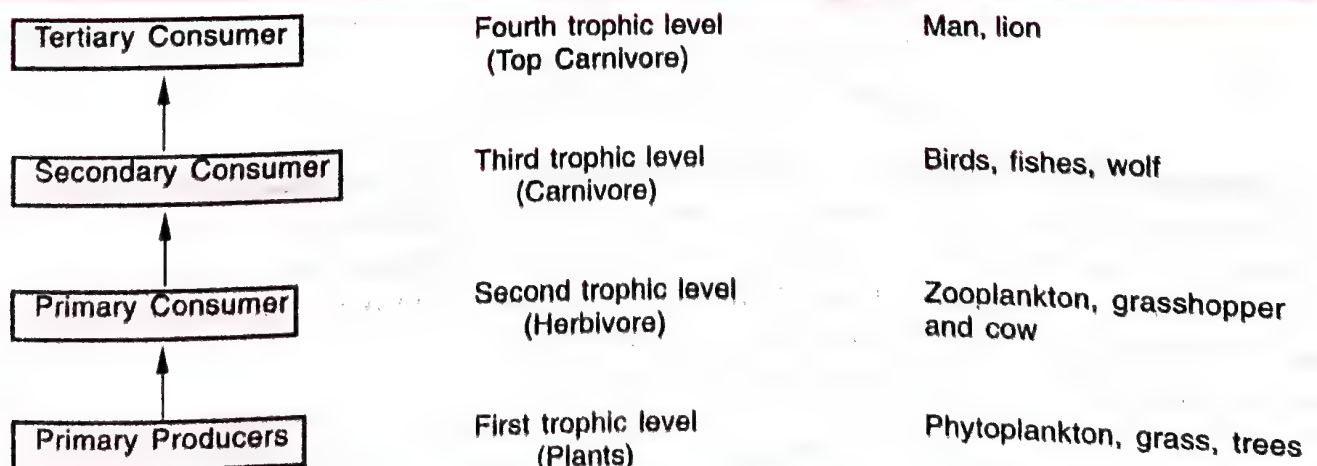


Fig. 14.6. Diagrammatic representation of trophic levels in an ecosystem.

Organisms of one trophic level have the same food habit, e.g., herbivory. However, each trophic level may have several resources like leaves, seeds, fleshy fruits, nectar, grasses, etc. A group of species belonging to a trophic level which exploits a common resource base in a similar fashion is known as **guild**, e.g., nectar feeding birds, grazing animals, browsing animals.

Trophic level is a functional level. Neither a guild nor a trophic level is occupied by a single species. A number of species may operate at it. A single species may occupy more than one trophic level. Sparrow is primary consumer if it feeds on seeds, fruits and peas. It is secondary consumer if it feeds on insects and worms. Consumers which feed on all types of foods are called omnivores, e.g., Cockroach, Crow. Human beings are also omnivores. Carnivorous (insectivorous) plants are both producers as well as carnivores though they digest the small animals like saprotrophs.

Food Chain

Definition. A food chain is a sequence of populations or organisms of an ecosystem through which the food and its contained energy passes with each member becoming the food of a later member of the sequence.

Characteristics

1. A food chain consists of series of populations which are related by eating and be eaten.
2. A food chain is generally straight.
3. The number of trophic levels is 3–6.
4. There is progressive reduction in available biomass, energy and number of individuals with the rise in trophic level.
5. In each trophic level a lot of biomass is consumed in liberating energy.
6. A major part of energy made available at each trophic level is lost as heat.
7. Some organisms like humans operate at more than one trophic level.
8. Food chains are sustained by producers and decomposers.

Types of Food Chains. Food chains are of three types— parasitic, detritus and grazing. **Parasitic food chain (PFC)**, also called **auxiliary food chain**, begins with host and usually ends in parasite.

Producer	→	Parasite
Herbivore	→	Parasite
Carnivore	→	Parasite

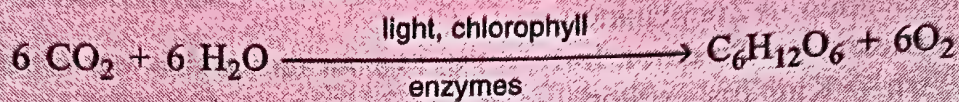
Detritus food chain (DFC) begins with detritus or dead organic matter. Detrivores and decomposers feed over it. Therefore, food energy present in detritus passes into them. In terrestrial ecosystem, a large amount of energy passes through detritus food chain. DFC is often connected to grazing food chain. Here detrivores and decomposers are consumed by smaller carnivores which in turn become food for larger carnivores and so on. A common detritus food chain with earthworm as detrivore is

Detritus	→	Earthworm	→	Sparrow	→	Falcon
		↘		Frog	→	Snake → Peacock

Grazing food chain (GFC) is the most common food chain. It is also called **predator food chain** as predation occurs at every step. GFC is the major conduit of energy flow in aquatic ecosystem.

Composition of Predator or Grazing Food Chain. The food chain consists of producers, consumers and decomposers. The latter are often omitted since they operate at all the levels of the food chain. Consumers are often of 3–5 types— first order (primary), second order (secondary), third order (tertiary), fourth order (quarternary) consumers.

1. **Producers.** They constitute the first trophic level or base of a food chain. Producers are autotrophic organisms which alone are able to manufacture organic food from inorganic raw materials in the process of photosynthesis. The energy for this process is obtained from solar radiations or sunlight. The latter is changed into chemical energy by chlorophyll. The chemical energy is used in combining raw materials into organic food. Oxygen is evolved in the process.



Organic food synthesised by producers consists of all essential ingredients like carbohydrates, fats, proteins, vitamins, etc. It contains energy. Part of the food manufactured by the producers is used up by themselves in providing energy for various body activities and in overcoming entropy. The rest is employed in their body building. Part or whole of the latter enters the food chain as food for consumers.

Producers are also known as **transducers** because they are able to change radiant or light energy into chemical form.

2. **Primary Consumers or Herbivores.** They are animals which feed on plants or plant products, e.g., grasshoppers and several other insects, rabbit, hare, field mouse, deer, antelope, elephant, zooplankton (*Paramecium*, *Daphnia*, some larvae), tadpoles, some fishes. A part of plant food eaten by herbivores become constituent of their body while a major part is consumed by them in production of energy for various body activities. Herbivores are also called **key industry animals** (Elton, 1927) because they convert plant matter into animal matter.

3. **Secondary Consumers or Primary Carnivores.** They ingest or prey upon herbivorous animals, e.g., frog, predator insects, several birds, fishes, wild cat, fox, jackal (also scavenger), etc. A part of flesh or food obtained from herbivore is used in body building by primary carnivore while the rest is consumed in providing energy for various life processes.

4. **Tertiary Consumers or Secondary Carnivores.** They are larger carnivores which prey upon primary carnivores, e.g., wolf (feeds on fox), snake (prey upon frog).

5. **Top Carnivores.** They are the last order consumers or carnivores which are not preyed upon by other animals because of their size, agility and ferociousness, e.g., shark, crocodile, eagle, peacock, tiger, lion.

A food chain may terminate at the level of herbivore (e.g., vegetation → elephant), primary carnivore (e.g., vegetation → squirrel → bear), secondary carnivore (vegetation → squirrel → wild cat → tiger), tertiary carnivore, etc.

Examples of some common food chains are given below :

(i) Food Chains on Land.

1. Grass → Grass Hopper → Frog → Snake → Peacock/Falcon.

2. Vegetation → Rabbit → Fox → Wolf → Tiger

3. Vegetation → Insect → Predator Insect → Insectivorous Bird → Hawk.

(ii) Food Chains in Water (Pond).

1. Phytoplankton → Zooplankton → Small Crustaceans → Predator Insects → Small Fish → Larger Fish → Crocodile.

2. Phytoplankton → Zooplankton → Small Crustaceans → Predator Insects → Small Fish → King Fisher/Stork.

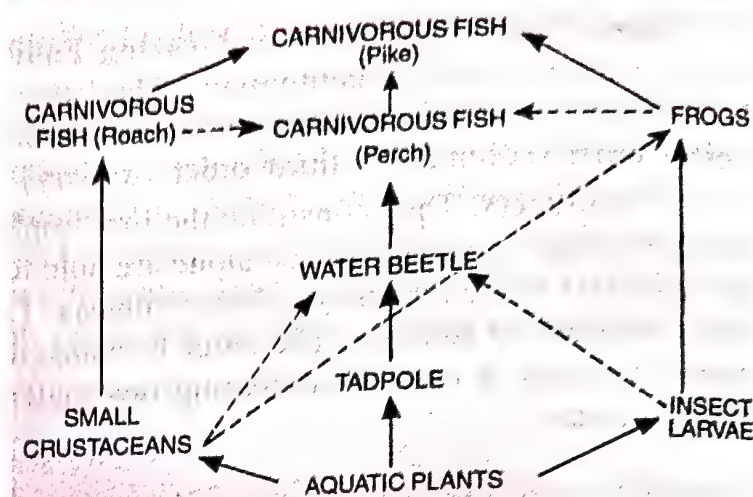


Fig. 14.8. An aquatic food web with the interconnected food chains.

Food Web

Definition. It is a network of food chains which become interconnected at various trophic levels so as to form a number of feeding connections amongst the different organisms of a biotic community. Food web is meant for increasing the stability of an ecosystem by providing alternate source of food and allowing the endangered population to grow in size.

Characteristics

1. Food web is more real than food chain.
2. It consists of a number of food chains interlinked at various trophic levels.
3. Food web is not straight. The component food chains do not run parallel.
4. It provides a number of alternate foods to consumers which, therefore, become **polyphagous**.
5. Feed back checks operate in food webs that keep the populations of different species nearly constant.
6. It is essential for stability of ecosystem.

Importance. Normally a food web operates according to taste and food preferences of the organisms at each trophic level. However, availability of food source and other compulsions are equally important. In Sunderbans, the tigers eat fish and crab in the absence of their natural preys. Some organisms normally operate at more than one trophic level. Thus human beings are not only

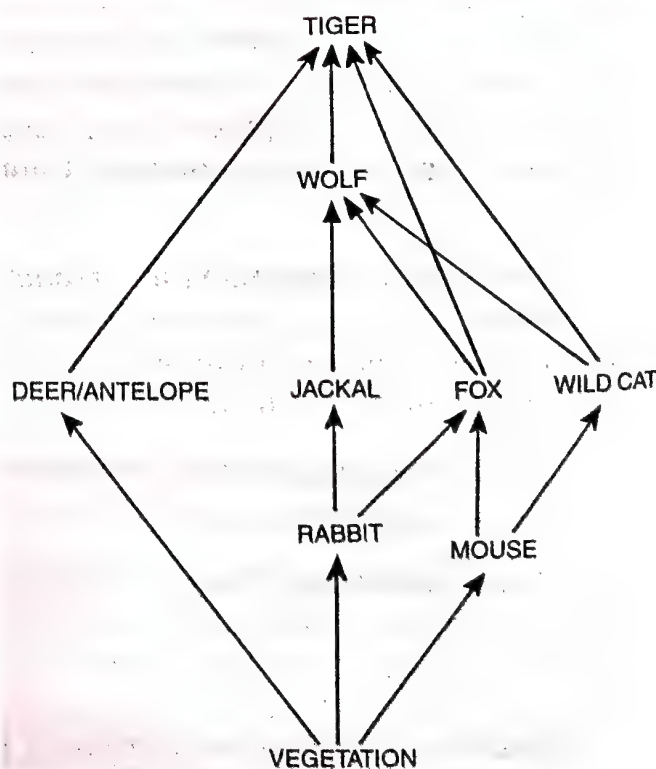


Fig. 14.9. A Terrestrial food web.

herbivores but also carnivores of various levels. Jackals are both carnivores and scavengers. Snakes feed on mice (herbivores) as well as frogs (carnivores). Wild cats prey upon mice as well as birds and squirrels. A wolf eats not only fox but also rabbit and deer. Therefore, the concept of food web appears more real ecologically than the concept of a simple food chain. The mechanism of operation of food web in maintaining stability of ecosystem is given below.

A herbivore like rabbit does not get starved if its preferred plant species is reduced in quantity due to some calamity. It begins feeding on alternate plant species. The preferred one gets chance to recover from the loss. Similarly, rabbits are preyed upon by foxes, wild dogs, wild cats, jackals, etc. In case the population of rabbit decreases, the predators begin to eat mice, shrews, squirrels, etc. Meanwhile rabbits increase their population and restore the balance.

Differences Between Grazing and Detritus Food Chains

<i>Grazing Food Chain (GFC)</i>	<i>Detritus Food Chain (DFC)</i>
<ol style="list-style-type: none"> 1. The chain begins with producers as the first trophic level. 2. Energy for the food chain comes from sun. 3. Food chain adds energy into the ecosystem. 4. The food chain binds up inorganic nutrients. 5. It supports detritus food chain by providing organic matter. 	<ol style="list-style-type: none"> 1. The chain begins with detritivores and decomposers as the first trophic level. 2. Energy for the food chain comes from organic remains or detritus. 3. It retrieves food energy from detritus and prevents its wastage. 4. The food chain helps in releasing inorganic nutrients to the cycling pool. 5. It supports grazing food chain by providing inorganic nutrients.

Differences between Food Chain and Food Web

<i>Food Chain</i>	<i>Food Web</i>
<ol style="list-style-type: none"> 1. It is a single straight pathway through which food energy travels in the ecosystem. 2. Members of higher trophic level feed upon a single type of organisms of lower trophic level. 3. Presence of separate or isolated food chains adds to the instability of the ecosystem. 4. It does not add to adaptability and competitiveness of the organisms. 5. Only the members of one trophic level compete for obtaining the same food. 	<ol style="list-style-type: none"> 1. It consists of number of interconnected food chains through which food energy passes in the ecosystem. 2. Members of higher trophic level can feed upon a number of alternative organisms of the lower trophic levels. 3. Presence of food webs increases the stability of the ecosystem. 4. Food webs increase adaptability and competitiveness of the organisms. 5. Competition is among members of different species. It is less severe as a number of alternate foods are available.

Energy Flow

Ecosystems require a constant input of energy as every component of an ecosystem is regularly dissipating energy. Two laws of thermodynamics govern this flow of energy. According to first law of thermodynamics, energy can be transferred as well as transformed

but is neither created nor destroyed. According to second law of thermodynamics every activity involving energy transformation is accompanied by dissipation of energy. Except for deep hydrothermal ecosystems, the source of energy in all ecosystems is solar energy. 50% of the solar energy incident over earth is present in **PAR (photosynthetically active radiation)**. About 1–5% of incident solar energy or 2–10% of PAR is captured by the photosynthetic organisms in synthesis of organic matter (Gross primary productivity). Roughly 20% of it is consumed in respiration so that net capture of energy (net primary productivity) is 0.8–4% of incident radiation or 1.6–8% of PAR (Fig 14.5). The value is 0.9% in savannah, 0.81% in mixed forests, 1.15% in grasslands, 5% in crops and 10–12% in sugarcane. Energy does not remain trapped permanently in any organism. It is either passed on to the higher trophic level or becomes available to detritivores and decomposers after the organism dies. Normally, herbivores feed on producers. Part of the food energy is wasted in digestion and assimilation. Some of the assimilated food is broken down to release energy for performing body activities. A very small portion becomes part of the body of herbivore. Herbivores are eaten by primary carnivores, the latter by secondary carnivores and so on. At every step a lot of energy is wasted.

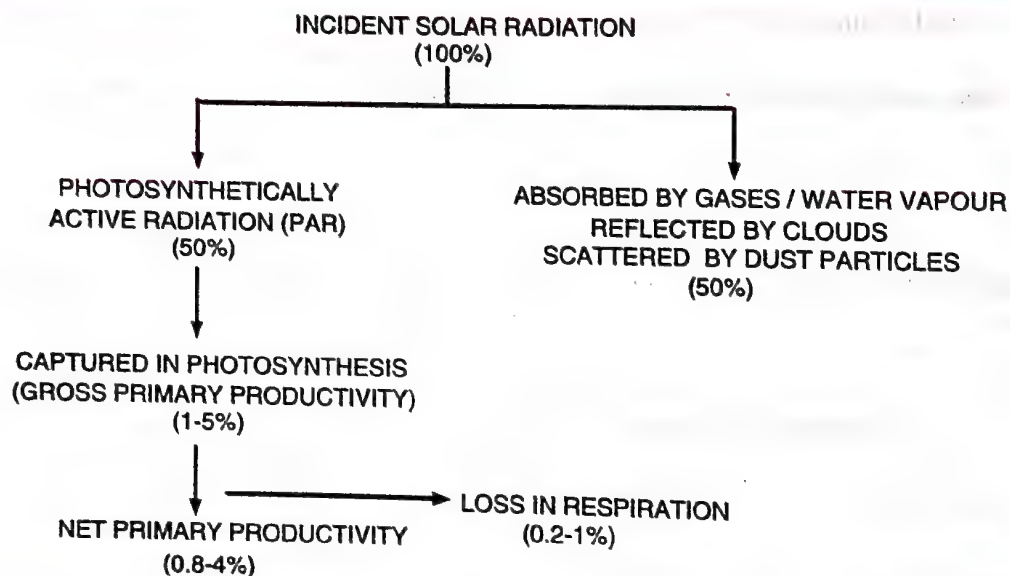


Fig. 14.9. Fate of solar energy incident on vegetation.

Energy Flow Model (Flow of Energy in Ecosystem)

Energy flow in an ecosystem is always unidirectional or one way, i.e., solar radiations → producers → herbivores → carnivores. It cannot pass in the reverse direction. There is decrease in the content and flow of energy with the rise in trophic level. A part of energy captured by producers (gross primary productivity) is used for maintenance (through liberation in respiration) and as food to herbivores. The remaining net productivity is either used by humans or passes into detritus chain. A lot of wastage of food occurs during ingestion by herbivores. Energy is used for digestion of food. A part is lost as faecal matter to decomposers. Part of assimilated food is also broken down to release energy in the process of respiration. A part of this energy is lost as heat. The remaining is used in performing various life activities and in overcoming entropy. Only 10% of the gross productivity of producers is entrapped by herbivores for their body building.

Herbivores are eaten by primary carnivores. Herbivores not preyed by carnivores die a natural death and energy trapped in their body is transferred to decomposers. Only 10% of the herbivore productivity is utilised for raising productivity of primary carnivores. The rest is consumed in ingestion, respiration, maintenance of body heat and other activities. Higher carnivores similarly are able to retain only 10% of energy present in primary carnivores. It is called 10% (ten percent) law which was proposed by Lindeman, 1942.

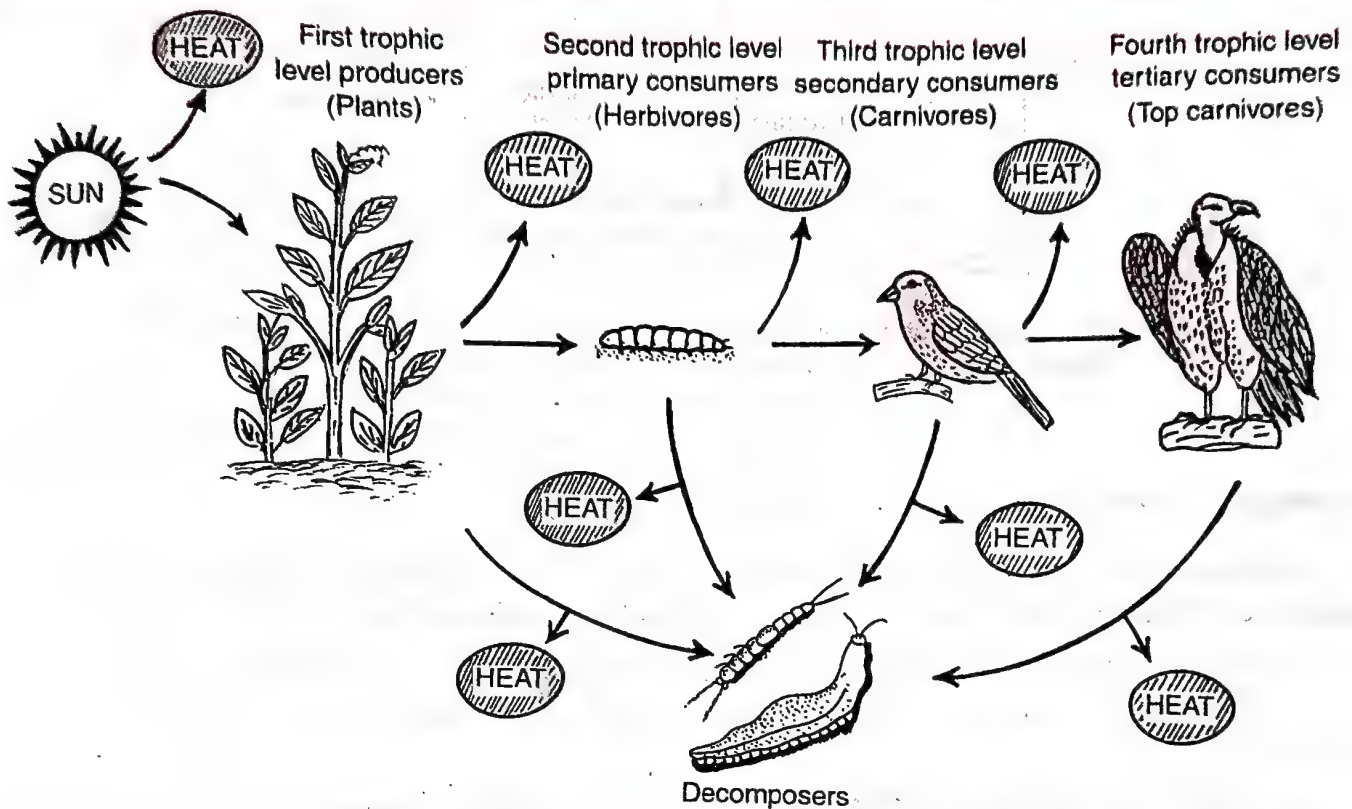


Fig. 14.10. Diagrammatic representation of energy flow through different trophic levels.

Respiration cost and energy requirement for maintenance of body rises with successively higher level. On an average, respiration of producers consumes about 20% of its gross productivity, 30% of assimilated energy in herbivores and upto 60% of assimilated energy in carnivores.

Nearly 90% of energy is lost when it moves from one trophic level to the next. Therefore, the residual energy decreases drastically within 2-3 trophic levels. As a result an ecosystem can support only a limited number of trophic levels, hardly 3-5.

Producer Biomass → Herbivore Biomass → Carnivore I Biomass → Carnivore II Biomass
 1000 K cal 100 K cal 10 K cal 1 K cal

Energy flow in the ecosystem is very important as it is the basis of life. Food provides both matter and energy. Flow of energy determines the diversity as well density of organisms. It also determines the development and functional status of the ecosystem.

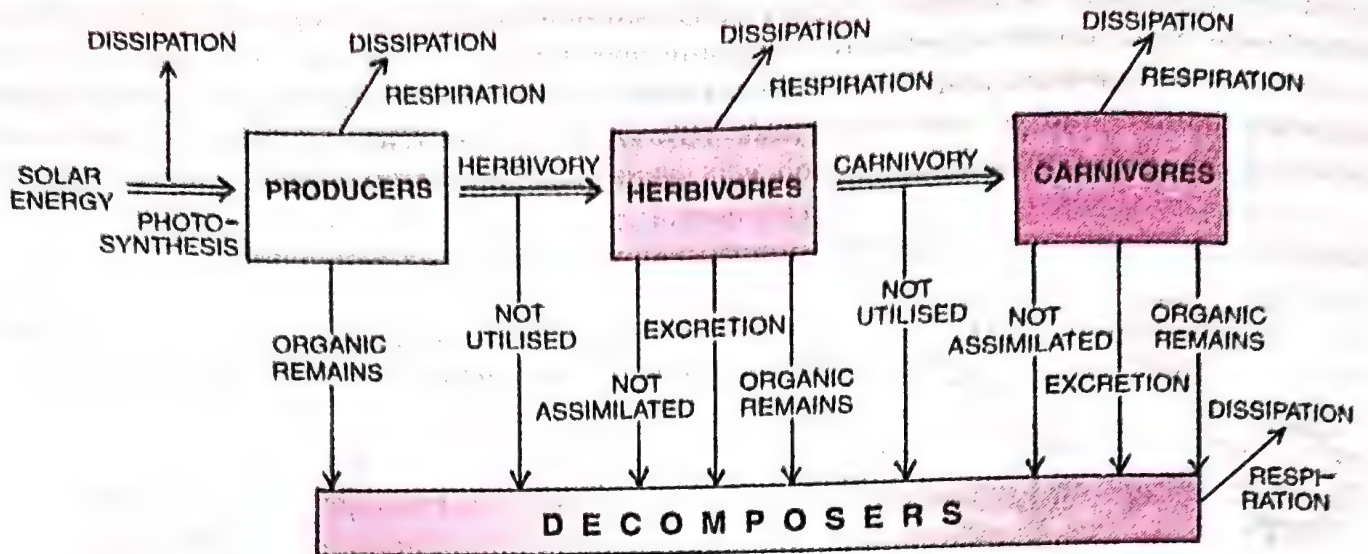


Fig. 14.11. A generalised energy flow model of ecosystem. Boxes represent biotic components and the arrows show the pathways of energy transfer (GPP = Gross Primary Productivity; A = as assimilation).

Number of Trophic Levels

Maximum number of trophic levels is hardly 3–5 in terrestrial ecosystems and 4–6 in aquatic ecosystems. The smaller number of trophic levels is due to

- (i) A lot of food is wasted as it passes from one trophic level to the next.
- (ii) For its activities and survival, each organism consumes a lot of energy through respiration.
- (iii) The whole biomass available at lower trophic level is not useful to the higher energy trophic level.
- (iv) Only 10% of the energy available at one trophic level passes to the next trophic level. Thus 1000 kcal of biomass energy makes available only 1 kcal of biomass energy at the level of carnivore II and 0.1 kcal of biomass energy at the level of carnivore III. Therefore, for supporting a higher trophic level organism a large amount of biomass is required at the producer level. A tiger requires an area of 240 sq km of forest for supporting itself.

Ecological Pyramids (Eltonian Pyramids)

An ecological pyramid is a graphic representation of an ecological parameter, like biomass energy or number of individuals present in various trophic levels of a food chain with producers forming the base and top carnivores the tip. Each trophic level represents a functional level. Therefore, it includes all the members of all the species operating at that level.

Ecological pyramids were developed by Charles Elton (1927) and are, therefore, also called **Eltonian pyramids**. In a pyramid the various steps of a food chain are represented sequence-wise with producers at the base, herbivores above them, followed by primary carnivores and so on with tip carnivores constituting the tip of the pyramid. An ecological pyramid can be **upright** (with larger base and gradually tapering towards the tip), **inverted** (narrow base, gradually becoming broader towards the tip) or **spindle shaped** (narrow both

at base and tip with a broader part in the middle). Pyramids are usually prepared for three ecological parameters—number of individuals, amount of biomass and amount of energy. Accordingly there are three types of ecological pyramids.

1. **Pyramid of Numbers** (Figs. 14.12–13). *It is a graphic representation of the number of individuals per unit area of various trophic levels stepwise with producers being kept at the base and top carnivores kept at the tip.* In most cases the pyramid of number is upright with members of successive higher trophic level being fewer than the previous one. The maximum number of individuals occur at the producer level. The producers support comparatively fewer number of herbivores, the latter fewer number of primary carnivores and so on. Top carnivores are very few in number. In a grassland, a larger number of grass plants or herbs support a fewer number of grasshoppers that support a still smaller number of frogs, the latter still smaller number of snakes and the snakes very few peacocks or falcons. A similar case is found in a pond ecosystem where a large number of phytoplankton support comparatively smaller number of zooplankton (like copepods), the latter fewer number of small-sized fishes, the small-sized fishes becoming food of still fewer larger-sized fishes or water birds.

The number of individuals in a higher trophic level is generally smaller than that of the lower trophic level because the organisms of the higher trophic level are dependent for their food and energy on the organisms of the lower trophic level. During transfer of food, about 90% of it is wasted or consumed up in respiration and only 10% becomes part of the higher trophic level. Therefore, in a food chain the members of

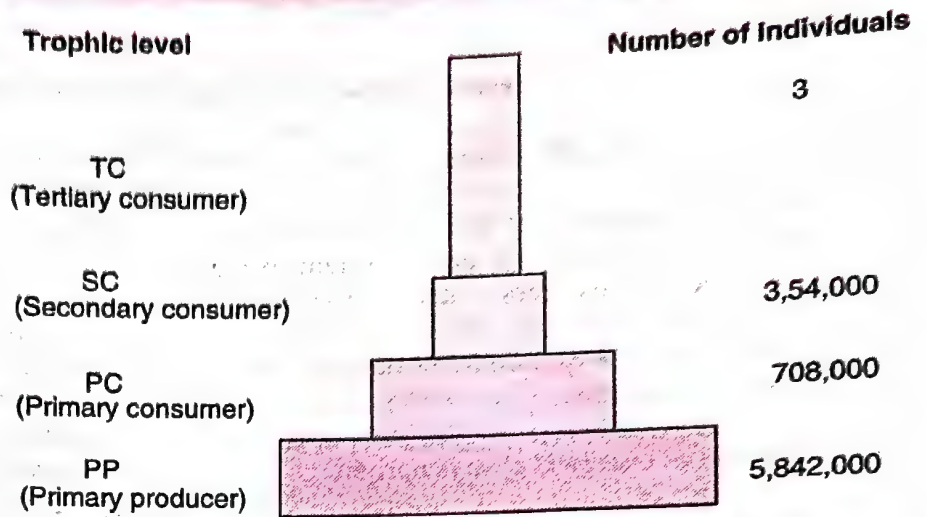


Fig. 14.12. Pyramid of numbers in grassland. Only three top carnivores are supported by a grassland having 6 million plants.

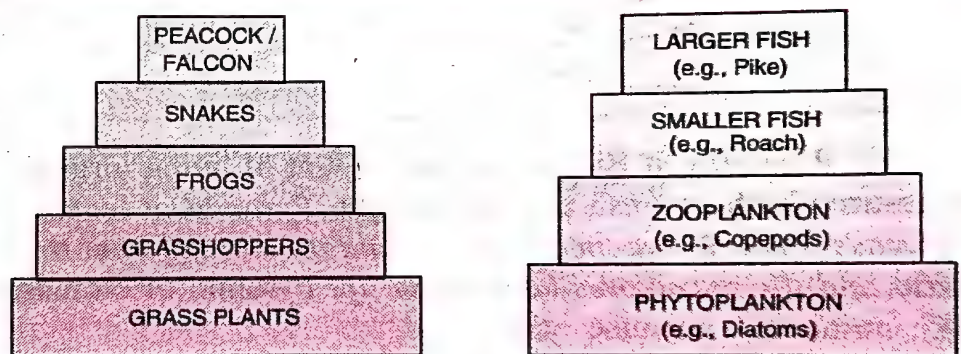


Fig. 14.13. Pyramids of number in terrestrial and pond ecosystem.

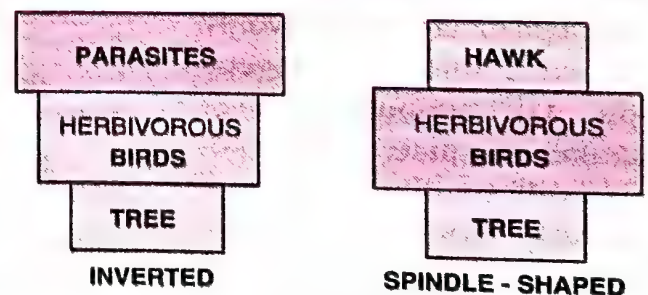




Fig. 14.14. Abnormal pyramid of Numbers. A, inverted B, spindle shaped.

successively higher trophic level are fewer in number. This is, however, not applicable in all the cases. A single large sized producer like tree can, however, provide nourishment to several herbivores (e.g., birds). The birds may support a still larger population of ectoparasites. Such a pyramid shall be inverted. Small sized herbivorous birds are usually eaten by falcon or eagle. The number of eagles is, however, very small. This type of pyramid of numbers shall be spindle-like (Fig. 14.14).

Differences between Upright and Inverted Pyramids

Upright Pyramid	Inverted Pyramid
<ol style="list-style-type: none"> 1. When the number of producers or their biomass is maximum in an ecosystem like grassland ecosystem and decreases progressively at each trophic level in a food chain, the pyramid of number and biomass is upright. 2. Pyramid of energy is always upright. 3. The base bar comprising producers is the largest and bar of vertex of the pyramid comprising top consumers is the smallest. 	<ol style="list-style-type: none"> 1. When the number of individuals or their biomass at producer level is minimum and increases progressively at each trophic level in a food chain, an inverted pyramid is formed e.g., pyramid of numbers in tree ecosystem, pyramid of biomass in aquatic/pond ecosystem. 2. Pyramid of numbers and pyramid of biomass may be inverted. 3. The base bar comprising producers is the smallest and the bar of vertex comprising top consumers is the largest.
	

2. Pyramid of Biomass. The amount of living organic matter is called biomass. It is measured both as fresh and dry-weight. *Pyramid of biomass is a graphic representation of biomass present sequence-wise per unit area of different trophic levels with producers at the base and top carnivores kept at the tip.* Pyramid of biomass is more real than the pyramid of numbers because the latter does not take into consideration the size of the individual. For example, mouse, shrew, squirrel, rabbit, deer, antelope, bison and elephant are all herbivores. The same amount of vegetation will support a large number of mice, fewer rabbits, still smaller number of deer and very few elephants. However, their total biomass shall be equal in all the cases and will be related to the biomass of the vegetation.

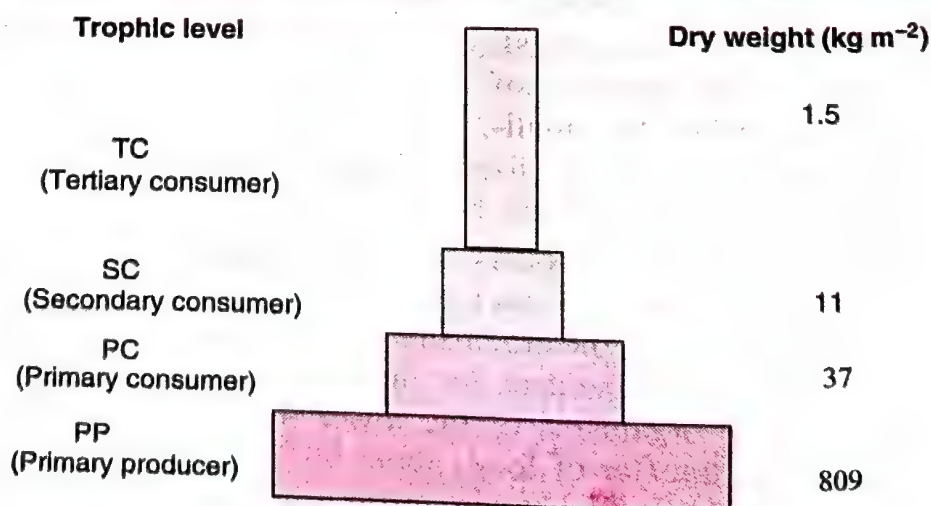


Fig. 14.15. Pyramid of biomass showing a sharp decrease at higher trophic level.

Maximum biomass occurs in producers. There is a progressive reduction of biomass found in herbivores, primary carnivores, secondary carnivores, etc. (Figs. 14.15.-16). It is lower trophic level to higher trophic level. The rest is consumed in providing energy for giving heat, overcoming entropy and performing various body activities. Thus 1000 kg of vegetation supports a biomass of only 100 kg of herbivores primary carnivore and only 1 kg in secondary carnivore. Therefore, the cost of production of food (meat) from animals is much higher than the one obtained directly from plants. A total dependence on animal diet will be disastrous. For example, the agriculture produce of Russia is at least twice that of India while its population is less than half of India. Even then Russia imports a large amount of grains while India has become a surplus country. It is because majority of Indians are vegetarians and they

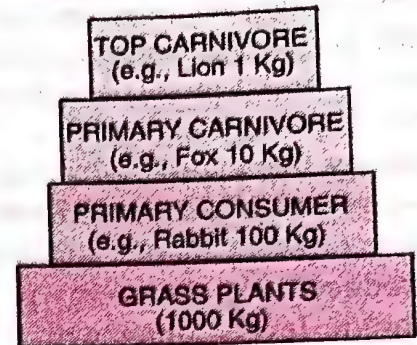


Fig. 14.16. Pyramid of biomass.

PC (Primary consumer)



21

PP (Primary producer)



4

Fig. 14.17. Inverted pyramid of biomass where a small standing crop of phytoplankton supports large standing crop of zooplankton.

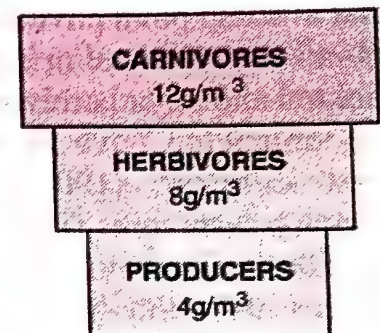


Fig. 14.18. Inverted pyramid of biomass in an aquatic system.

obtain their food mostly from first trophic level while Russians are mostly nonvegetarians and depend upon second trophic level (herbivores) for their subsistence.

Pyramid of biomass is upright for terrestrial habitats. Inverted or spindle-shaped pyramids are obtained in aquatic habitats where the biomass of a trophic level depends upon reproductive potential and longevity of its members. Thus the biomass of phytoplankton may be smaller than that of zooplankton and that of the latter less than of primary carnivores. However, if total biomass produced per unit time is calculated, the pyramid of biomass shall always be upright.

3. **Pyramid of Energy.** It is a graphic representation of amount of energy trapped per unit time and area in different

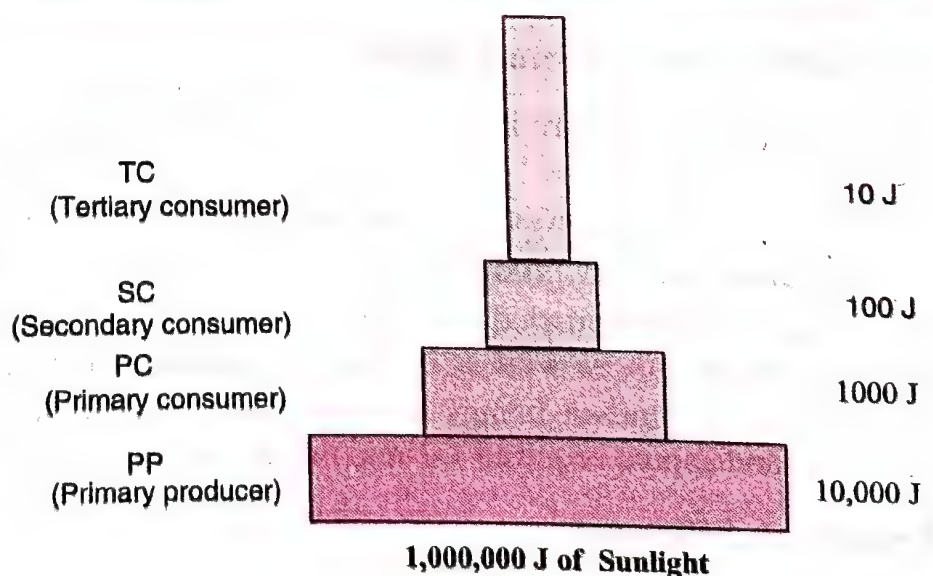


Fig. 14.19. An ideal pyramid of energy with primary producers storing only 1% of solar energy as NPP.

trophic levels of a food chain with producers forming the base and top carnivores the tip. The energy content is expressed as kcal/m²/yr or KJ/m²/yr. Maximum energy content is present in producers. They obtain the energy from solar radiations. The energy is converted in chemical form and stored inside organic matter manufactured by the producers. As the energy passes into higher trophic levels along with food, its amount decreases because of its dissipation as heat and use in overcoming entropy as well as for performing various body activities.

The data given by Odum (1971) shows that in a fish pond phytoplankton trap 31080 kJ/m²/yr (7400 kcal/m²/yr) of energy. Zooplankton and other herbivores dependent upon phytoplankton have an energy content of 7980 kJ/m²/yr (1900 kcal/m²/yr). The primary carnivores (insect larvae and small fish) possess an energy content of 2100 kJ/m²/yr (500 kcal/m²/yr). They support secondary carnivores with an energy content of 126 kJ/m²/yr (30 kcal/m²/yr). If the latter is eaten by human beings only 16.8 kJ/m²/yr (4 kcal/m²/yr) of energy content is stored. Thus pyramid of energy is always upright. It is more accurate than the pyramid of biomass or the pyramid of numbers.

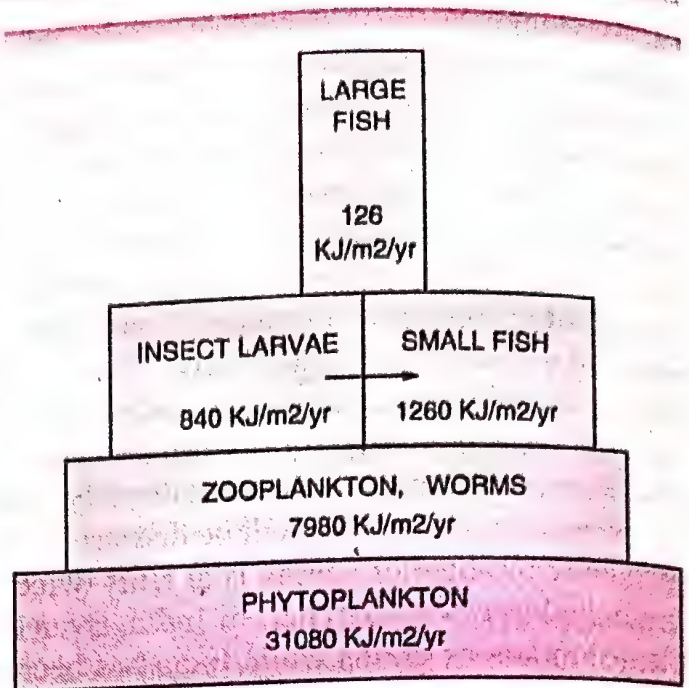


Fig. 14.20. Pyramid of energy in a fish pond.

Limitations of Ecological Pyramids

1. Ecological pyramids assume that food chains are simple. Simple food chains do not occur in nature. Instead, food webs are present.
2. A single species may operate at two or more trophic levels. Ecological pyramids have no method of accommodating such cases.
3. Ecological pyramids have no place for detritivores and decomposers though they play a vital role in ecosystem.

Importance of Ecosystem Study

1. Ecosystem study indicates the available solar energy and the efficiency of an ecosystem to trap the same.
2. It gives information about the available essential minerals and their recycling periods.
3. Gross and net productivity of an ecosystem are known.
4. It provides knowledge about the web of interactions and inter-relations amongst the various populations as well as between populations and the abiotic environment.
5. It helps human beings to know about conservation of resources, protection from pollution and inputs required for maximising productivity.

Ecological Efficiency

The ratio between the energy assimilated over the energy available between two trophic levels is called ecological efficiency. It was first studied by Lindeman (1942) who called it as **progressive efficiency**. Knowledge of ecological efficiencies is useful in knowing the

degree to which organisms of a trophic level exploit food energy resource and convert the same into biomass. The various ecological efficiencies are as follows:

(i) **Photosynthetic Efficiency.** It is the percentage of incident solar radiations trapped by producers to perform photosynthesis and produce gross primary productivity.

$$\text{Photosynthetic Efficiency} = \frac{\text{Energy in Gross Primary Productivity}}{\text{Energy in incident solar radiations}} \times 100$$

Photosynthetic efficiency is 1–5%. It can also be expressed in relation to PAR when it is 2–10%.

(ii) **Net Production Efficiency.** It is percentage of net primary productivity in relation to gross primary productivity. Tree species with large amount of nonphotosynthetic biomass have lesser net production efficiency than small sized producers.

$$\text{Net Production Efficiency} = \frac{\text{Net Primary Productivity}}{\text{Gross Primary Productivity}} \times 100$$

(iii) **Assimilation Efficiency.** It is the percentage of food energy assimilated for body building to total food ingested.

$$\text{Assimilation Efficiency} = \frac{\text{Food Energy Assimilated}}{\text{Food Energy Ingested}} \times 100$$

(iv) **Ecological Efficiency/Trophic Level Efficiency.** The percentage of energy converted into biomass by a higher trophic level over the energy of food resources available at the lower trophic level is called ecological efficiency.

$$\text{Ecological Efficiency} = \frac{\text{Energy Converted into Biomass at Trophic Level}}{\text{Energy Present in Biomass at Lower Trophic Level}} \times 100$$

Biotic or Ecological Succession

Biotic or ecological succession is the natural development of a series of biotic communities at the same site, one after the other till a climax community develops which does not change further because it is in perfect harmony with the environment of the area. The change is orderly and sequential. There is a parallel change in the physical environment. Rather, succession occurs because each biotic community changes the environment of the area that suits another biotic community more than itself.

The first biotic community which develops in a bare area is called **pioneer community**. It has very little diversity. This stage takes the longest time to change the environment for invasion of the next community. **Climax community** is the stable, self perpetuating and final biotic community that develops at the end of biotic succession and is in perfect harmony with the physical environment. It is also termed as climatic climax community. Climax community has maximum diversity and niche specialization. The various biotic communities that develop during biotic succession are termed as **seral** or **transitional communities**. The entire sequence of development stages of biotic succession from pioneer to a climax community is known as **sere**. The series of development stages of biotic succession in an arid area is termed as **xerosere** while biological succession on an arid area is called **xerarch**. Xerosere is of further two types : (i) **Lithosere**. Sequence of successional stages on a bare rock. (ii) **Psammosere**. Sequence of successional stages on sand. The various stages of biotic succession taking place in a water body are collectively termed as **hydrosere** while such a succession is known as **hydrarch succession**.

Differences between Pioneer Community and Climax Community

Pioneer Community	Climax Community
<ol style="list-style-type: none"> 1. It is the first biotic community which develops in bare area. 2. Pioneer community is established over a previously bare area. 3. Pioneer community consists of a few small sized organisms. 4. The area is hostile for pioneer community. 5. It develops soil. 6. The community consists of hardy organisms. 7. Life span of organisms is short. 8. Growth is fast. 9. It is soon replaced by the next seral community. 	<ol style="list-style-type: none"> 1. It is final biotic community that develops in an area. 2. Climax community occurs over an area previously occupied by seral communities. 3. Climax community consists of numerous large and small sized organisms. 4. The area is favourable for the climax community. 5. It grows on built up soil. 6. The community consists of normal or non-hardy organisms. 7. Life span of component organisms is generally long. 8. Growth is slow. 9. Climax community is stable. It is not replaced by any other community.

Changes During Biotic Succession

- (i) Small short lived plants (r-selection) to large long-lived plants (k-selection).
- (ii) Unstable biotic community to stable biotic community.
- (iii) Little diversity to high degree of diversity.
- (iv) Greater niche specialization.
- (v) Increase in biomass.
- (vi) Increase in soil differentiation.
- (vii) Increase in humus content of soil.
- (viii) Aquatic or dry conditions to mesic conditions.
- (ix) Simple food chains to complex food webs.
- (x) Reduction in productivity/standing crop (P/B).
- (xi) Increase in respiratory consumption and decrease in productivity till ultimately the two become equal, $P = R$ or $P/R = 1$.
- (xii) Reduction in environment perturbations.

Differences between Seral Community and Climax Community

Seral Community	Climax Community
<ol style="list-style-type: none"> 1. It is transitional community which develops in an area during succession. 2. Seral community is replaced by an other subsequent successional community. 3. Food chains and food webs are simple. 4. Biomass is small. 5. Diversity is of lower degree. 6. Niches are fewer and generalized. 7. Size of the individuals is small. 8. Nutrient conservation is low. 	<ol style="list-style-type: none"> 1. It is final community that develops in an area at the end of biotic succession. 2. Climax community is seldom replaced. 3. Food chains and food webs are complex. 4. Biomass is high. 5. Diversity is of higher degree. 6. Niches are many and specialized. 7. Size of individuals is both large and small. 8. Nutrient conservation is high.

Types of Ecological Succession

Depending upon the type of nudity of the area, ecological or biotic succession is of two types, primary and secondary.

1. **Primary Succession** (= *Prisere*). It is a biotic succession that occurs on a previously sterile or primarily bare area. Newly exposed sea floor, igneous rocks, sand dunes, new cooled lava sediments or newly submerged areas are some of the examples of primary bare area. It is quite hostile to first life or pioneer community. Primary succession takes a very long time. It is often one thousand to several thousand years. It is because soil which is essential for establishing a biotic community takes several hundred to several thousand years depending upon the substratum and the climate.

2. **Secondary Succession** (= *Subsere*). It is a biotic succession that occurs in an area which became secondarily bared due to destruction of the community previously present there. Destruction of the previous community or secondarily bared area can occur due to (a) Forest fire (b) Submergence by major flood (c) Recently cleared area left to itself (d) Harvested crop fields left uncultivated for several years. (e) Heavily overgrazed area left to itself. (f) Landslide or earthquake. (g) Severe drought for successive years. The secondarily bared area has a built in soil organic matter. It is biologically fertile so that succession is completed quickly. Underground parts, some seeds, remnant species and invaders quickly give rise to a new community as soon as conditions become favourable. The community undergoes a few seral changes and ultimately gives rise to climatic climax community. Secondary succession takes 50–100 years to complete in case of grassland and 100–200 years for development of a forest. The species that are adapted to colonise newly disturbed habitats are called **fugitive species**. The early colonisers in secondary succession depend upon condition of soil, availability of water, presence of seeds and other propagules. Sometimes, the secondarily bared area may be invaded by moss *Sphagnum* or exotic weeds like *Lantana camara* and *Eupatorium odoratum*. This affects succession seriously and the climax community is never regenerated.

Differences between Primary Succession and Secondary Succession

Primary Succession	Secondary Succession
<ol style="list-style-type: none"> 1. It occurs in an area which has been bare from the beginning. 2. Soil is absent at the time of beginning of primary succession. 3. There is no humus in the beginning. 4. Reproductive structures of any previous community are absent. 5. Pioneer community comes from outside. 6. In the beginning the environment is very hostile. 7. Seral communities are many. 8. Primary succession takes a long time for completion, 1000 years or more. 	<ol style="list-style-type: none"> 1. Secondary succession occurs in an area which has been denuded recently. 2. Soil is present in the area where secondary succession begins. 3. Humus is present from the very beginning. 4. Reproductive structures of the previous occupants are present in the area. 5. Pioneer community develops partly from previous occupants and partly from migrants. 6. The environment is favourable from the beginning. 7. Seral communities are a few. 8. Secondary succession takes less time for completion, 50–200 years.

Biotic Succession on Bare Rock (Lithosere, Xerosere)

The sequence of successional stages that occur on bare rocks is called **lithosere**. Because the bare rock is deficient in water, the lithosere is also called **xerosere**. The bare rocky habitat is extremely hostile to living beings. There is no water as the substratum does not absorb rain water. There is no nutrient holding mechanism. When exposed to sun, the surface temperature goes very high. Plants cannot grow on these rocks. The first inhabitants or pioneers of such a habitat are usually lichens in the temperate region and blue green algae in tropical region. The various seral stages are as follows :

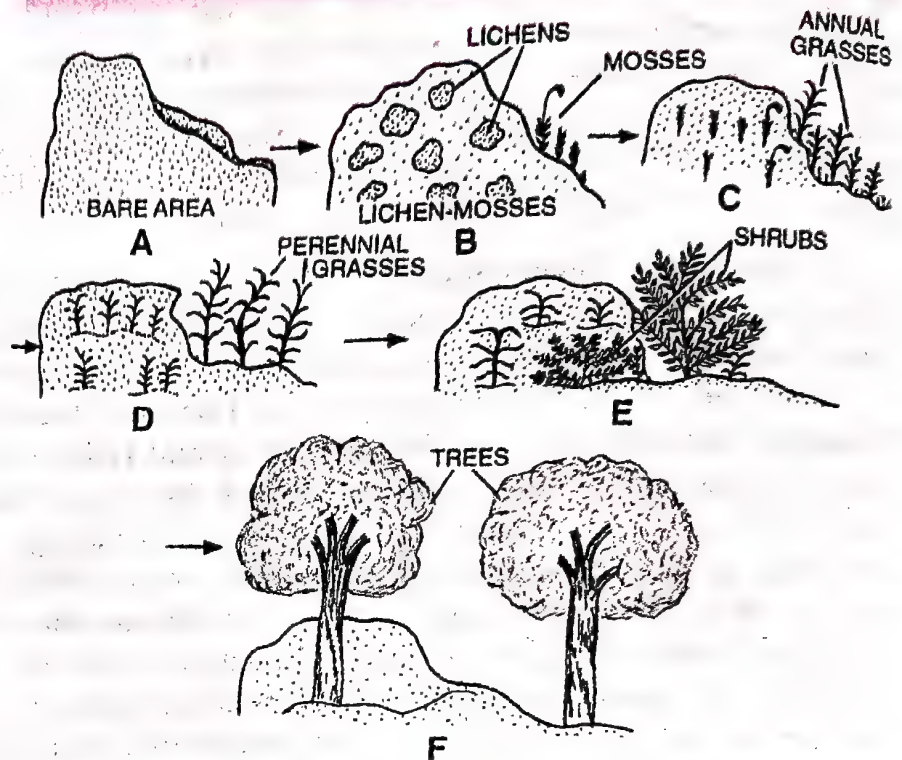


Fig. 14.21. Biotic succession on a bare rock.

1. Lichen Stage. Wind borne lichen propagules settle on the wet rock surface soon after rain or heavy dew. They develop very fine rhizoids for attachment. The pioneer lichens are usually crustose lichens, e.g., *Graphis*, *Rhizocarpon*. Lichens can tolerate desiccation, heating during summer noon or excessive cooling during winter nights. They bring about slow weathering of rocks and formation of soil. For this they secrete lichen acids and carbonic acid. The acids slowly corrode rock surface and release minerals required for proper growth of lichens. Corrosion produces small depressions. With time the wind borne soil particles and organic matter from dead lichen parts collect in them. This invites larger lichens called foliose lichens, e.g., *Dermatocarpon*, *Parmelia*. The foliose lichens increase shading of the rock, cause deeper depressions and accumulate more soil particles as well as organic matter. The foliose lichens kill the crustose lichens by shading them.

2. Moss Stage. Foliose lichens growing on rocks make the conditions favourable for growth of hardy mosses (e.g., *Tortula*, *Grimmia*). Mosses are of larger size, have gregarious habit and their rhizoids penetrate deeper in the rocks. They shade the lichens and hence replace the same. Mosses accumulate more soil and organic matter. The substratum remains moist for longer periods. Weathering and fragmentation of rock starts. This invites more moisture loving mosses (e.g., *Hypnum*, *Bryum*). Ultimately the spot becomes suitable for invasion by next stage.

3. Annual Grass Stage. The mat formed by mosses on the partially fragmented rock becomes sufficiently moist during the rainy season for germination of seeds of annual grasses and other hardy herbs, e.g., *Aristida*, *Poa*, *Eleusine*. The grasses grow for a couple of months when there is moisture. Their roots penetrate deeper into the rock and cause its further fragmentation. This increases moisture and soil. The soil becomes favourable for growth of longer lived annual grasses. The process of soil accumulation continues.

4. **Perennial Grass Stage.** Annual grasses are replaced by perennial grasses due to increased moisture and soil in the rock crevices. The perennial grasses have runners and rhizomes which rapidly spread the grasses, e.g., *Cymbopogon*, *Heteropogon*. Shade, moisture, soil, perennial vegetation and seeds invite several small animals.

5. **Shrub Stage.** Seeds and rhizomes of xerophytic shrubs, invade the area occupied by perennial grasses, e.g., *Zizyphus*, *Caparis*, *Rhus*, *Rubus*. Shrubs are larger and their roots reach greater depth causing further cracks in the rocky substratum and hence helping in more soil formation. The shrubs shade the area, make it more moist and invite hardy trees and several types of animals.

6. **Climax Community.** Several hardy and light demanding trees grow in the area occupied by shrubs. Slowly environment becomes more moist and shadier so that plants of climax community spread in the area. Type of climax community depends upon the climate. Therefore, it is also called climatic climax community. It is a rain forest in a moist tropical area, a coniferous forest or deciduous forest in temperate area. Grassland appears in area with less rainfall. The shrubs and tree stages are then omitted.

Biotic Succession in Newly Formed Pond/Lake (Hydrosere)

Series of biotic communities that develop one after the other in a newly formed pond or lake is called **hydrosere**. It starts as soon as the muddy water becomes clear. The various successional or seral stages of hydrosere are :

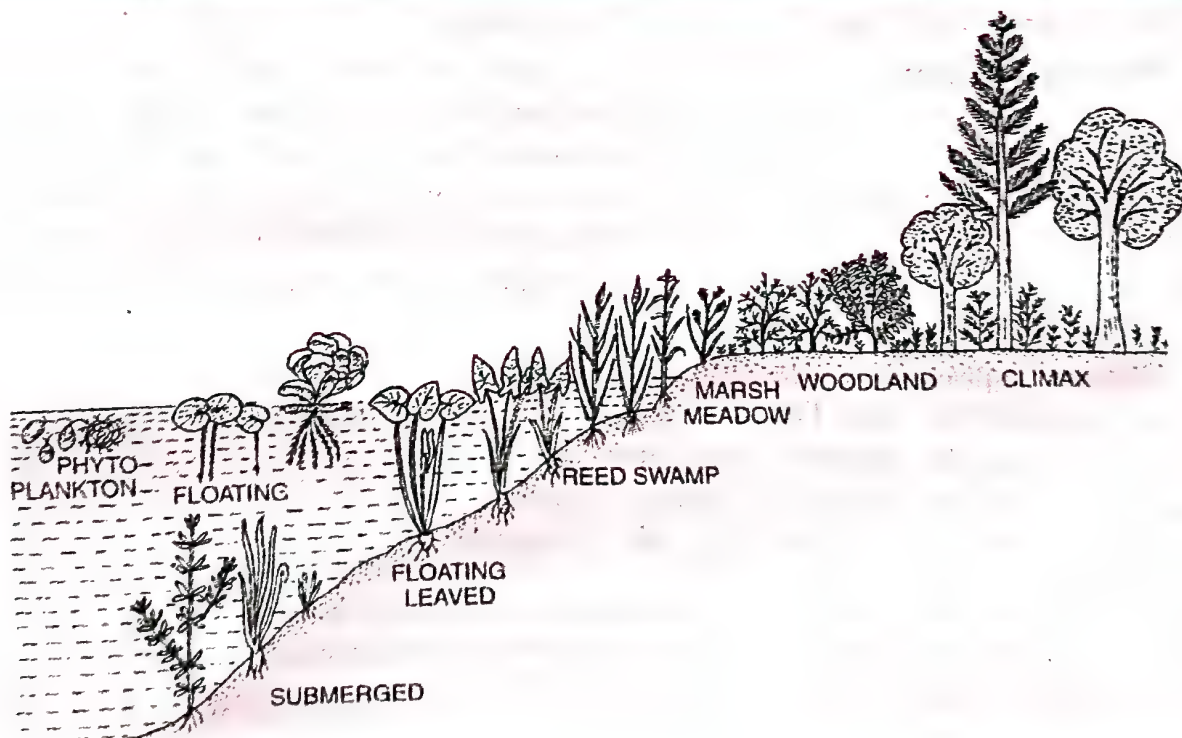


Fig. 14.22. Stages in biotic succession in a lake/pond.

1. **Plankton Stage.** It is the pioneer stage of hydrosere. Spores of this stage reach the water body through wind or animals. The first to appear are minute autotrophic organisms called **phytoplankton**, e.g., diatoms, green flagellates, single-celled colonial or filamentous green algae as well as blue-green algae. They multiply rapidly. Soon a balance is created by the appearance of **zooplankton** which feed on phytoplankton. Death and decomposition of

plankton produce organic matter. The latter mixes up with clay and silt at the bottom to form soft mud favourable for growth of next seral stage.

2. **Submerged Stage.** The bottom lined by soft mud having organic matter is favourable for growth of submerged plants like *Hydrilla*, *Potamogeton* and *Najas*. They are rooted in the mud and form dense growth. As a result sand and silt get deposited around the plants. The bottom level, therefore, rises slowly. The older plants and buried parts of other plants form humus on their death and decay. This enriches the newly built up bottom and makes it favourable for growth of next stage.

3. **Floating Stage.** Floating leaved anchored plants (e.g., *Nymphaea*, *Nelumbo*, *Nuphar*) appear where water becomes shallow. These plants have subterranean stems like rhizome and tuber. The plants make the water rich in mineral and organic matter. It becomes suitable for growth of free floating plants like *Lemna*, *Spirodela*, *Wolffia*, *Azolla*, *Eichhornia*, etc. They cover the water quickly. Rapid growth of floating stage further builds up bottom so that water becomes shallow on the periphery.

4. **Reed Swamp Stage.** Amphibious plants grow where the water body becomes shallow (0.3–1.0 m), e.g., *Phragmites*, *Typha*, *Scirpus*, *Sagittaria*. The plants of swamp stage transpire huge quantities of water. They also produce abundant organic matter. Their tangled growth accumulates silt.

5. **Sedge or Marsh Meadow Stage.** The shores built up by reed swamp stage are invaded by *Carex* (Sedge), *Cyperus*, *Juncus*, grasses like *Themeda* and *Dichanthium* and herbs like *Campanula*, *Caltha*, *Polygonum* etc. The plants transpire rapidly and add abundant humus. Therefore, soil is build up to invite next stage.

6. **Woodland Stage.** The periphery of sedge meadow stage is invaded by some rhizome bearing shrubby plants which can tolerate bright sunlight as well as water logged conditions, e.g., *Cornus* (Bogwood), *Cephalanthus* (Button Brush). The shrubs shade away the plants of sedge meadow stage. They invite invasion by trees capable of bearing bright sunlight and water logging, e.g., *Populus* (Cottonwood), *Alnus* (Alder). The plants of woodland stage lower the water table by their transpiration. They also built up more soil. Shade loving plants come to grow below them.

7. **Climax Forest.** New trees invade the area. They have shade loving seedlings. These trees grow to greater heights. The trees and shrubs of woodland stage disappear. The climax forest depends upon the climate—rain forest in moist tropical area and mixed coniferous or deciduous forest in temperate area. A mixed temperate forest includes broad leaved trees like *Quercus* (Oak), *Ulmus* (Elm) and *Acer*, and gymnosperms like *Abies* (Fir), *Taxus* (Yew) and *Picea* (Spruce).

Differences between Succession on Land and Succession in Water

<i>Succession on Land</i>	<i>Succession in Water</i>
1. It begins with lichens or blue green algae.	1. It begins with phytoplankton.
2. Initial succession is a slow process.	2. Initial succession is quite fast.
3. Succession is seen all over the area.	3. Succession is observed in area where water is not very deep.
4. The whole of the area is involved in formation of climax community.	4. Climax community develops on the edge only.
5. Succession converts xeric environment to mesic environment.	5. It converts aquatic environment into mesic environment.
6. It reduces bare land area and converts into fertile forested area.	6. It fills up water body and changes it into forested land.

Importance of Biotic Succession

1. Sequence of biotic succession is usually fixed. Ecologists can immediately recognise the seral stage of a biotic community found in an area.
2. It tells us how a biotic seral stage like grasses and herbs of a pasture can be maintained by not allowing the biotic succession to proceed further through interference like grazing and fire.
3. Information gained through biotic succession is used in having controlled growth of one or more species by preventing their superiors to invade the area, *e.g.*, maintenance of Teak forest.
4. Dams are protected by preventing siltation and biotic succession to occur.
5. It gives information about the techniques to be used during reforestation and afforestation.

Changes in Community Characteristics During Succession

Community Structure	Seral	Climax
(i) Size of individuals	Small	Large
(ii) Niches	Few, generalised	Many, specialised
(iii) Community Organisation	Simple	Complex
Community Functions		
(i) Food Chains and Food webs	Simple	Complex
(ii) Efficiency of Energy use	Low	High
(iii) Nutrient Conservation	Low	High
(iv) P/B	High	Low
(v) P/R	$P > R$	$P = R$

Nutrient Cycles

They are exchanges, storage and transfers of biogenetic nutrients through various components of ecosystem so that the nutrients can be used again and again. The term **biogeochemical cycling** is used for exchanges/circulation of biogenetic nutrients between living and nonliving components of biosphere.

Biogenetic Nutrients/Biogeochemicals. They are essential elements required by organisms for their body building and metabolism which are provided by earth and return to earth after death and decay of the organisms. The amount of biogenetic nutrients present at any time in the growth medium of the ecosystem is called **standing state**.

Simple organic compounds like carbohydrates are built up of C, H and O obtained from CO_2 and water. Synthesis of other complex organic substances require additional nutrients or essential elements, *e.g.*, P and N in nucleotides, S and N in protein. Their requirement varies from element to element, some in large quantities (*e.g.*, N, P), others in traces only (*e.g.*, Zn, Mo, Cu).

There are two stores of nutrients, reserve pool and cycling pool.

Reservoir Pool. It is the reservoir of biogenetic nutrients from which the latter are slowly transferred to cycling pool, *e.g.*, phosphates in rocks. Rate of release depends upon environmental factors like moisture, pH, temperature, soil, etc. The function of reservoir is to meet deficient of nutrient which occurs due to differences in rate of influx and efflux.

Cycling Pool. It is the pool of biogenetic nutrients which is being emptied and filled repeatedly by exchange between biotic and abiotic components of biosphere.

Gaseous Cycles of Matter. Here the materials involved in circulation between biotic and abiotic components of biosphere are gases or vapours and the reservoir pool is atmosphere or hydrosphere, e.g., Carbon, Hydrogen, Oxygen, Nitrogen, Water.

Sedimentary Cycles of Matter. Materials involved in circulation between biotic and abiotic components of biosphere are nongaseous and the reservoir pool is lithosphere, e.g., Phosphorus, Calcium, Magnesium. Sulphur has both sedimentary and gaseous phases. Gaseous cycles are rapid and more perfect as compared to sedimentary cycles.

Differences between Gaseous and Sedimentary Nutrient Cycling

<i>Gaseous Nutrient Cycling</i>	<i>Sedimentary Nutrient Cycling</i>
1. The biogenetic material is basically gaseous.	1. The biogenetic material is basically nongaseous.
2. Reservoir pool is atmosphere/hydrosphere.	2. Reservoir pool is lithosphere.
3. It is very quick.	3. It is usually slow.
4. These cycles are nearly perfect.	4. These cycles are less perfect.
5. Withdrawal from reservoir pool is small.	5. Withdrawal from reservoir pool is large.

Differences between Nutrient Cycles and Flow of energy

<i>Nutrient Cycles</i>	<i>Flow of energy</i>
1. It involves circulation (cycling) of nutrients between abiotic and biotic components of the ecosystem.	1. The flow of energy is unidirectional and noncyclic.
2. There is no dissipation of nutrients at any level.	2. There is dissipation of energy at every level.
3. Reservoir pools of nutrients occur on earth.	3. Energy pools do not occur on earth.
4. All nutrients belong to earth.	4. Energy supply is from outside.
5. Microorganisms have an important role in maintaining nutrient cycles.	5. Microorganisms have little role in flow of energy.

Components. Nutrient cycles have three components or aspects— input, output and internal cycling.

(i) **Input of Nutrients.** An ecosystem receives an input of nutrients from external sources and stores the same for use in biological processes. Input of nutrients is of four types— **wet deposition** from rainfall, **dry deposition** from dust fall, **biological nitrogen fixation** and **weathering of rocks**.

Differences between Wet and Dry Deposition

<i>Wet Deposition</i>	<i>Dry Deposition</i>
1. It is the input of nutrient in an ecosystem in dissolved state.	1. It is an input of nutrients in an ecosystem in the particulate state.
2. Wet deposition usually occurs through rainfall.	2. It usually occurs through dust fall.
3. The input enters the atmosphere first usually in the form of gases.	3. The input enters the air usually as dust from eroded mining or industrial area.

(ii) **Output of Nutrients.** It is loss of nutrients from an ecosystem due to run off water (e.g., Ca^{2+} , Mg^{2+}), soil erosion, denitrification, harvesting of crops, felling of trees, cattle grazing, etc. In undisturbed ecosystem, the input and output of nutrients are minor and more or less balanced. However, severe disturbance in the ecosystem (like soil erosion, fire, insect and pest infection, tree felling) will make the nutrient cycles unbalanced and the ecosystem unstable.

(iii) **Internal Nutrient Cycling.** Soil is being depleted of its nutrients due to absorption by plants. A part of the absorbed nutrients is passed on to consumers through various trophic levels. Replenishment of the soil nutrients occurs through recycling. For this the soil receives bound nutrients regularly in the form of above ground detritus (leaf fall, dry twigs, animal remains, faecal matter, excretions) and underground detritus (e.g., dead roots). The nutrients are released from detritus through the activity of decomposers. In mature ecosystems, the amount of nutrient uptake is equal to amount of recycled nutrient. However, in young and growing ecosystems, nutrients uptake is more so that a lot of nutrients are retained by the growing biomass of biota. Retention = Uptake - Recycle. By determining the requirement of nutrient retention, the capacity of nutrient recycling, nutrient input and nutrient output, the nutrient budget of an ecosystem can be computed.

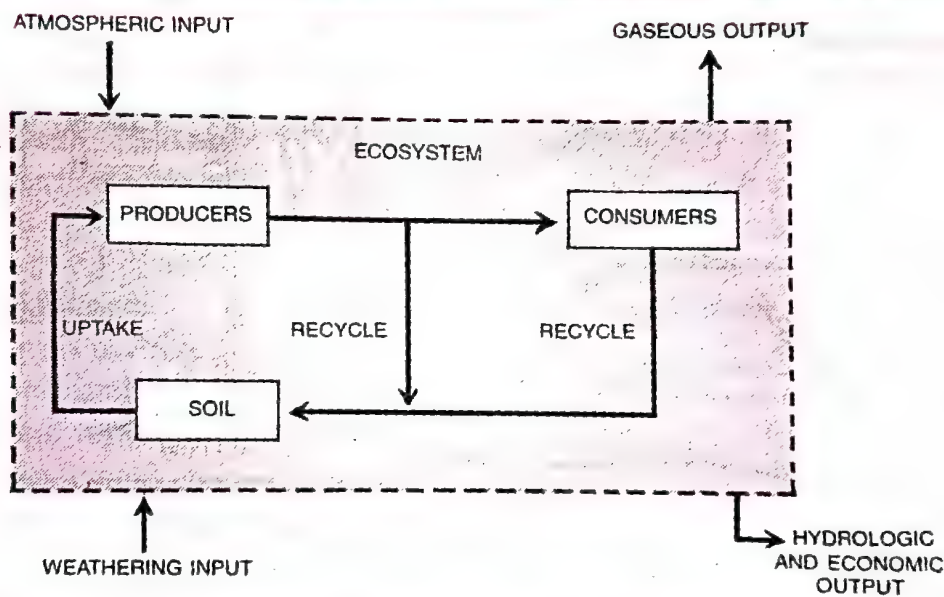


Fig. 14.23. A generalised model of ecosystem nutrient cycling.

Common Biogeochemical Cycles

The biogeochemical cycles of carbon, phosphorus are described below.

The Carbon Cycle (Figs. 14.24–25)

Importance of Carbon. Carbon is a component of all organic compounds of protoplasm like carbohydrates, lipids, proteins, nucleic acid, enzymes, hormones, etc. It constitutes 49% of dry weight and is, therefore, next only to water in abundance.

Source of Carbon. It is present in the abiotic environment in four forms; (i) Carbon dioxide in **air** or atmosphere (ii) Dissolved carbon dioxide or carbonic acid and bicarbonate in **water** or hydrosphere (iii) **Fossil fuels** like coal, petroleum, and natural gas (iv) Carbonates and graphite in the **rocks**.

Carbon Content and its Recycling. The cycling pool consists of 6×10^{14} Kg (29%) of free CO_2 in the atmosphere and 1.45×10^{15} Kg (71%) of dissolved CO_2 occurs in the oceans. Oceans also regulate the amount of CO_2 in the atmosphere. **Reservoir pool** is lithosphere. Lithosphere contains 2.8×10^{21} kg of carbon. Carbon present in the lithosphere does not become available to organisms till it is burnt or changed chemically. Carbon present in the atmosphere and hydrosphere is picked up by producers in the process of photosynthesis and changed to organic compounds. It is estimated that annual amount of carbon fixed in photosynthesis and changed to organic compounds is 4×10^{13} kg. Oxygen is released as a by-product. One hectare of healthy and productive forest produces 10,000 kg of oxygen and absorbs 30,000 kg of carbon dioxide (or 8,000 kg of carbon).

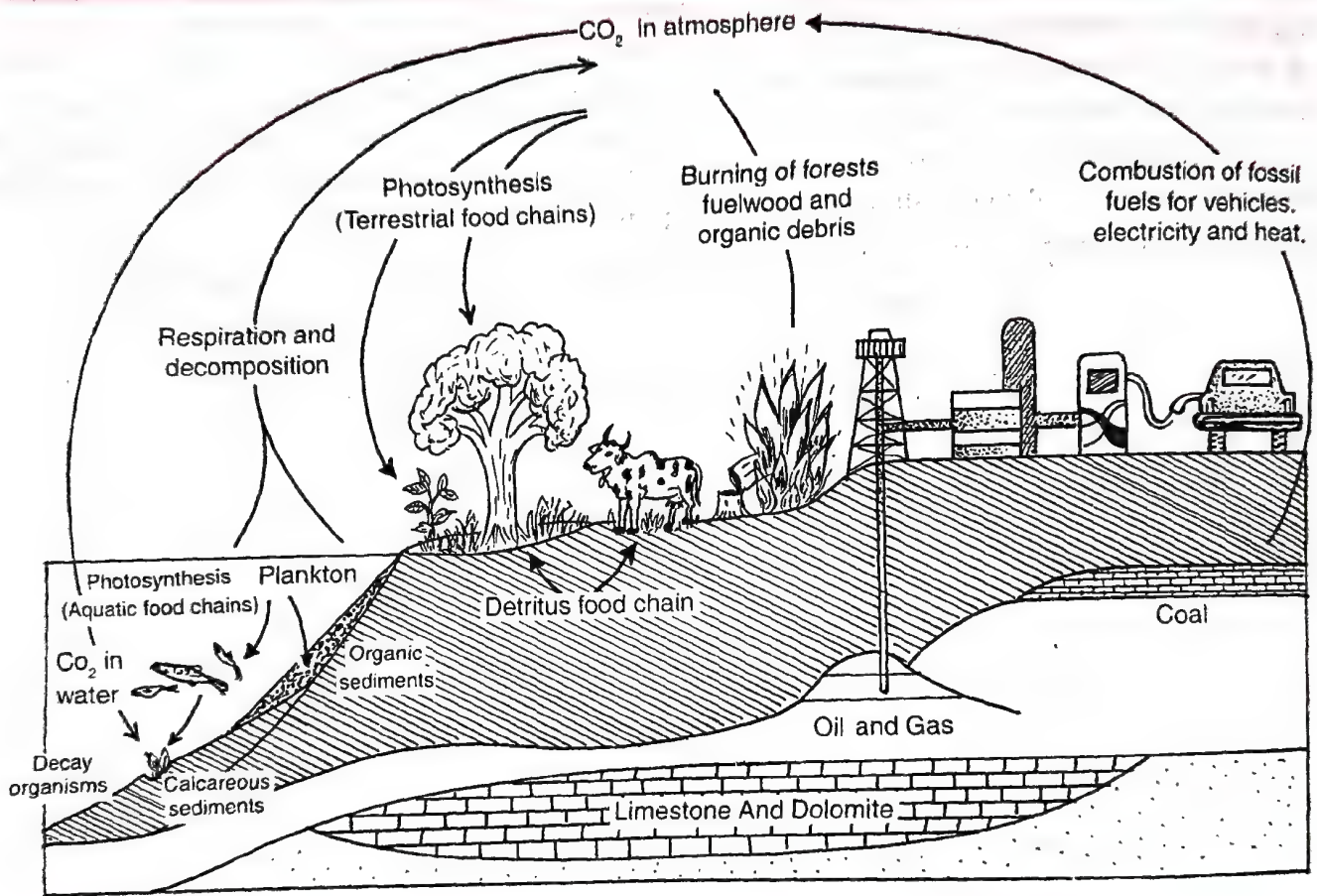


Fig. 14.24. Simplified model of Carbon cycle.

Carbon fixed by producers enters the food chain and is hence passed to herbivores, carnivores, decomposers, etc. During photosynthesis, the carbon component of the atmosphere and hydrosphere decreases. It is replenished by five methods : (i) Respiration of organisms. (ii) Decomposition of organic wastes and dead bodies by decomposers. (iii) Burning of wood and fossil fuels. (iv) Weathering of carbonate containing rocks or treatment of carbonate minerals. (v) Volcanic eruptions and hot springs. (vi) Forest fires. An exchange of CO_2 is also occurring between atmosphere and hydrosphere. Rather oceans function as **global sink** for a lot of CO_2 being produced in combustion.

Some carbon is being taken out of circulation and added to lithosphere by hard carbonaceous shells, skeletons of animals, fossilisation, seepage of carbon rich water into interior of earth and caving in of forests during earthquakes. The latter form coal and oil.

Natural exchange between lithosphere and hydrosphere or atmosphere is a very slow process. Major exchange in carbon cycle is between organisms (absorption by producers, released by all in respiration) and the atmosphere or hydrosphere. This cycling is a self-regulated feed back system but has recently been upset due to rapid deforestation and increasing combustion of fossil fuels. The latter are adding more than 6×10^{12} kg of carbon annually into the atmosphere. As a result carbon dioxide content of the atmosphere is increasing. It is liable to disturb the climatic conditions of the world and melt away polar as well as alpine ice resulting in 18–20 m rise in sea level.

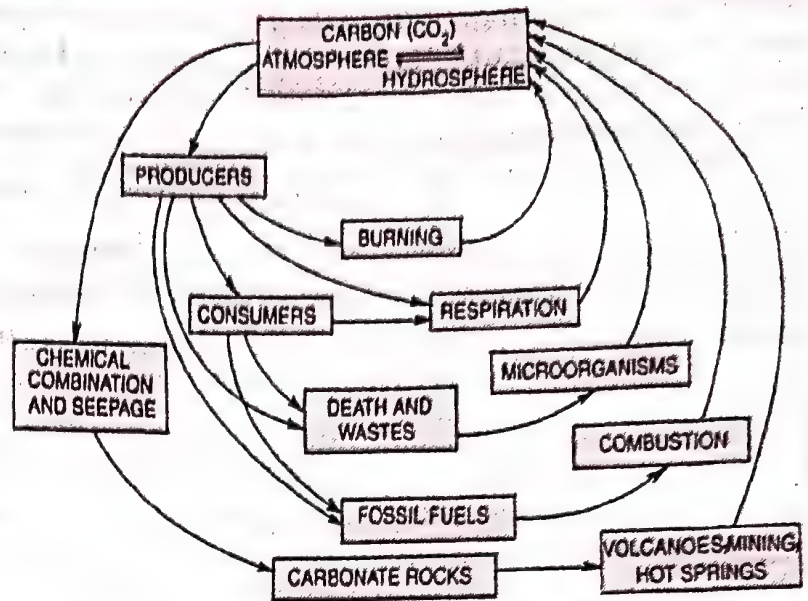


Fig. 14.25. Carbon Cycle.

The Phosphorus Cycle (Fig. 14.26)

Importance of Phosphorus. Phosphorus is component of nucleic acids, biomembranes as phospholipids, cellular transfer system as ATP, body structure as shells, bones and teeth. It takes part in metabolic reactions involved in release of energy from food and utilization of this energy in various functions of the body.

Main Sources. Phosphorus is mostly used as phosphate. Its **reservoir pool** is phosphate rocks while cycling pool is soil for terrestrial ecosystems and water for aquatic ecosystems. Small amount of phosphate is always being added to cycling pool through weathering of rocks. Phosphate is generally found in soil in combination with calcium, iron and aluminium. Atmosphere or gaseous cycle is absent. Phosphate circulates in the abiotic environment in lithosphere as well as hydrosphere. Aquatic habitats sometimes have an excess concentration of phosphorus. Excess is obtained from soil wash, industrial wastes as well as detergents.

Use and Release. Phosphate present in the soil may occur in the insoluble form. It is dissolved by chemicals secreted by micro-organisms and plant roots. The dissolved phosphate is absorbed by the plants and changed to organic form. Phosphate fertilizers are added to the soil to increase its availability. Soil obtained from lake or ocean bed and guano (excreta of marine birds) are also good source of phosphorus. From plants, phosphorus travels to animals along with the food chain. Animal excretions and dead bodies of organisms are acted upon by decomposers. Phosphorus is released in the process. The same becomes available for re-utilization by plants.

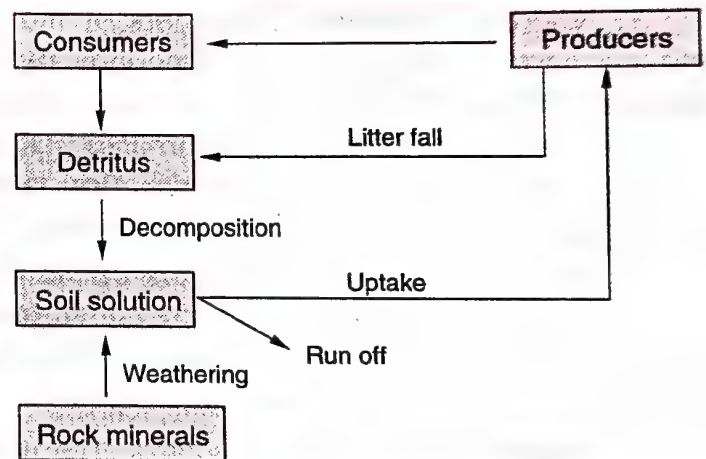


Fig. 14.26. A simplified model of Phosphorous cycle.

Inside soil some phosphorus is lost through leaching. Similarly a sufficient amount of phosphorus combines with calcium, iron or aluminium and becomes insoluble. It settles down at the bottom of lake or ocean as sediment. Bones and teeth may also remain undegraded. Such phosphorus becomes part of lithosphere. It is released after a very long interval when the rocks containing them are exposed to weathering agencies or are mined.

Differences between Carbon and Phosphorus Cycles	
Carbon Cycle	Phosphorus Cycle
1. Its major component is gaseous.	1. Its major component is nongaseous.
2. There is respiratory release of carbon as CO_2 .	2. There is no respiratory release of phosphorus.
3. Its cycling pool is present in hydrosphere and atmosphere.	3. Its cycling pool is lithosphere.
4. Atmospheric input of carbon through rainfall is appreciable.	4. It is negligible.

Ecosystem Services

The products of ecosystem processes which have environmental, aesthetic and indirect economic value are named as ecosystem services. For best services the ecosystems must be healthy.

1. **Carbon Fixation.** Producers of the ecosystem pick up CO_2 from the atmosphere and convert it into organic compounds in the process of photosynthesis. This not only sustains the ecosystem but also provides food to others outside the ecosystem, e.g., tribals, migratory animals. Carbon fixation also maintains the CO_2 balance of the atmosphere. The stress on tree plantation and afforestation is also due to it. Otherwise CO_2 concentration is going to rise very rapidly due to increase in fossil fuel combustion.

2. **Oxygen Release.** Producers of the ecosystem release a lot of oxygen during photosynthesis. Amazon rain forests are called **lungs of our planet** because they produce nearly 20% of oxygen. Release of oxygen by the producers helps in replenishing the gas being consumed in respiration and combustion.

3. **Pollination.** It is an essential step in the reproduction of plants. Several plants are adapted to get pollinated by particular animals like bees, butterflies, moths, birds, etc. The animals in turn, depend upon plants for their food. Elimination of the pollinator will eliminate the plant species due to non-reproduction. A number of pollinators coming from forests are engaged in pollinating our crop plants, fruit plants and others. Absence of these plants will naturally deprive the animals of their food. They will die of hunger.

4. **Seed Dispersal.** Many plants depend upon animals (birds, squirrels, terrestrial animals) for dispersal of their seeds. The plants provide the animals with food in the form of fleshy fruits and other edibles. They mutually support one another.

5. **Soil.** Soil formation and soil protection are the major ecosystem services accounting for nearly 50% of their total worth. Plant cover protects the soil from drastic changes in temperature. There is little wind or water erosion as soil particles are not exposed to them. The soil remains spongy and fertile. There are no landslides and no floods.

6. **Perennial Water.** Plant litter and humus prevent run off of water, hold water like sponge and allow percolation of water. A lot of water is held in the soil which slowly passes towards perched water table. It comes out as springs. They are a source of perennial fresh water which is quite pure.

7. **Air.** Plant cover of natural ecosystems absorb polluting gases, cause settling of suspended particulate matter, removes CO_2 and releases O_2 . A purified air becomes available.

8. **Wetlands.** They protect the land from floods, remove sediments and other pollutants and recharge ground water.

9. **Climate.** There is increase in atmospheric humidity, good rainfall and moderating effect on climate.

10. **Tribals.** A large number of tribals live in forests.

11. **Grazing Grounds.** They are grazing areas for numerous cattle.

12. **Other Values.** Natural ecosystems are a source of spiritual, cultural and aesthetic values.

Robert Constanza and his colleagues have put the value of ecosystem services to 33 trillion dollars. It is nearly twice the global GNP of 18 trillion dollars. 50% of it is for protection of soil, prevention of floods and mitigating droughts. The value is 10% each for nutrient cycling and recreation. It is 6% each for climate regulation and habitat for wildlife.

ADDITIONAL INFORMATION

- **Coldest Place.** Antarctic with air temperature of -88°C . Second coldest is Dhar (India) with temperature of -72°C .
- **Winogradsky (1891).** Discovered nitrogen fixation.
- **Standing State.** Amount of biogenetic or inorganic materials present in the abiotic environment per unit area at any time.
- **Standing Crop.** Amount of living material present in an ecosystem or biome present at any time.
- **Aboriculture** is the cultivation and management of individual specimens of ornamental trees.
- **Canopy** is the part of a woodland or forest community that is formed by the trees.
- **Phenology.** The ecological society of America defined phenology as the science of dealing with the appearance of certain events during life cycle of an organism found in nature.
- Gujarat has the largest number of salt lakes in India.

- **Single Channel Energy Flow Models.** Energy flow through an ecosystem was explained by E.P. Odum stating that as the flow of energy takes place, there is a gradual loss of energy at every level, thereby resulting in less energy available at next trophic level. The flow of energy takes place in a **unidirectional** manner through a single channel of green plants (producers) to herbivores and carnivores (Fig. 14.27). The **energy** which is passed to the next trophic level is **never reverted back** to the lower level. Thus organisms at higher trophic level always depend upon the organisms at lower trophic level for their energy requirements. Thus due to one way flow of energy, the ecosystem will collapse, if the primary source (the sun) was not there.

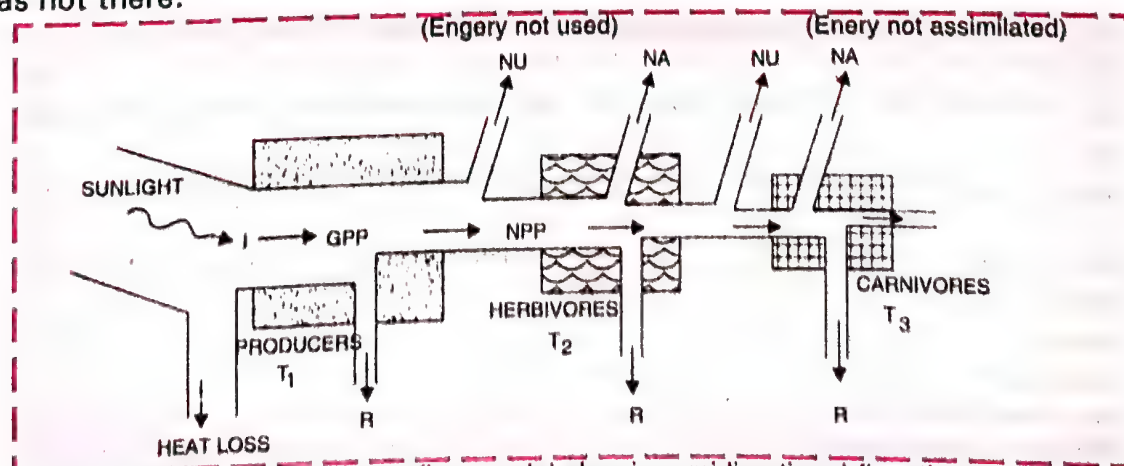


Fig. 14.27. One-way energy flow model showing unidirectional flow through primary producers, herbivores and carnivores.

- Y-shaped Model of Energy Flow.** It is also called double channel model, given by H.T. Odum (1956). In nature, both grazing and detritus food chains operate in the same ecosystem. However, sometimes grazing food chain (open sea ecosystem) or detritus food chain (forest ecosystem) predominates. In nature, these two chains seem to be separated, but are not so. Some dead animals which were a part of grazing food chain become incorporated in the detritus food chain like the faeces of grazing animals. When shown in the form of a diagram, this interdependence look like the letter Y. This double channel model shows the passage of energy through these two food chains. This model is more real and practical than single channel model, as it separates the grazing and detritus food chains in both time and space (Fig. 14.28).

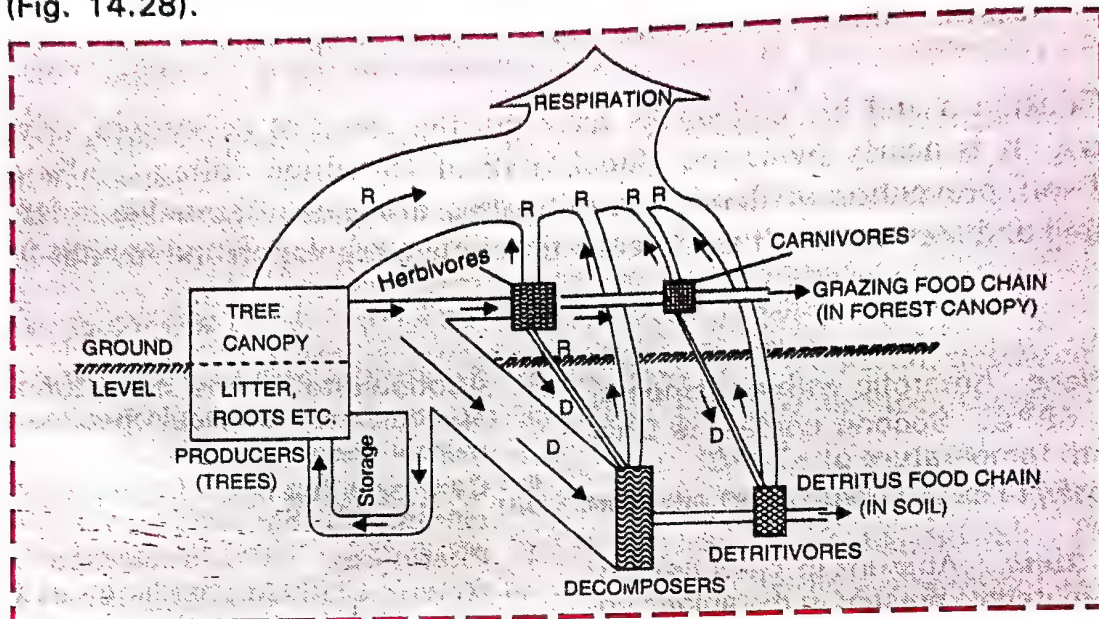


Fig. 14.28. Y-shaped or 2-channel energy flow model showing energy flow through the grazing food chain and the detritus food chain (R = Respiration, D = Detritus or dead matter)

NCERT TEXT BOOK QUESTIONS WITH ANSWERS

- Fill in the blanks:
 - Plants are called _____ because they fix carbon dioxide.
 - In an ecosystem dominated by trees, the pyramid of number is _____ type.
 - In aquatic ecosystems, the limiting factor for productivity is _____.
 - Common detritivores in our ecosystem are _____.
 - The major reservoir of carbon on earth is _____.

✓ (a) producers (b) spindle (c) light (d) earthworm, mites (e) ocean (also lithosphere as carbonate rocks)
- Which one of the following has the largest population in a food chain? (a) Producers (b) Primary consumers (c) Secondary consumers (d) Decomposers.

✓ (a)
- Second trophic level in a lake is (a) fishes (b) Phytoplankton (c) zooplankton (d) benthos.

✓ (c)
- Secondary producers are (a) herbivores (b) all consumers (c) carnivores (d) producers.

✓ (b)
- What is the percentage of photosynthetically active radiations (PAR) in the incident solar radiation? (a) 50% (b) 100% (c) 1–5% (d) 2–10%.

✓ (a)
- Describe the components of an ecosystem.

✓ An ecosystem has two types of components, biotic and abiotic.

Biotic Components. They are living organisms found in an ecosystem. Biotic components are of five types — producers, consumers, detritivores, decomposers and parasites.

(i) **Producers.** They are autotrophs which synthesize organic food from inorganic nutrients with the

help of solar energy. The process is called photosynthesis. Solar energy is changed into chemical energy of food.

(ii) **Consumers.** They are animals which feed on other organisms.

Herbivores feed on plants. **Carnivores** prey upon other animals. Depending upon trophic level they are called primary carnivores (second order consumers), secondary carnivores (third order consumers) and top carnivores which are not preyed upon by others.

(iii) **Detritivores.** They feed on detritus causing its fragmentation and pulverisation, e.g., Earthworm, Vulture.

(iv) **Decomposers.** They are saprophytes which pour digestive enzymes over the organic matter for its solubilisation. It results in humification and mineralisation of organic matter.

(v) **Parasites.** They belong to different groups which obtain food from other living organisms called hosts.

Abiotic Components. They include climate, edaphic and topographic factors.

1. **Temperature.** There are four temperature zones — tropical, subtropical, temperate and arctic or alpine. Different types of organisms occur in different zones.

2. **Light.** Photosynthesis depends upon the availability of light which is maximum in tropical areas and decreases progressively towards poles. Plants growing under shade of large trees show less photosynthetic activity. In the form of photoperiods, light influences a number of activities including flowering, leaf fall, migration and breeding in many animals.

3. **Wind.** It influences transpiration, pollination, dissemination, tree growth and flight animals.

4. **Humidity.** It influences luxuriance of biota.

5. **Precipitation.** Amount and periodicity of rainfall control forest type of the area. Water availability and humidity also depend upon rainfall.

6. **Water.** Depending upon its availability, plants are xerophytes, mesophytes, hydrophytes and hygrophytes.

7. **Background.** Most animals have colour, pattern and texture similar to background.

8. **Topography.** Topography or surface behaviour of earth influences other abiotic factors.

9. **Gases.** CO_2 concentration determines the rate of photosynthesis and warmth of the atmosphere. Oxygen concentration is supra optimum for C_3 plants and optimum for C_4 plants.

10. **Soil.** It determines vegetation growth and pattern.

11. **pH.** Tree growth is favoured by slightly acidic pH. Earthworms do not occur in acidic soils. *Euglena* and other flagellates are abundant.

12. **Mineral Elements.** Both excess and deficiency of minerals are harmful to biota. Optimum mineral elements are required for optimum growth.

7. Define ecological pyramids and describe with examples, pyramids of number and biomass.

✓ **Definition.** Refer to the text.

Pyramid of Numbers (Definition as in text). It is generally upright with producers population (e.g., grass plants, phytoplankton) being the largest. Producers support fewer herbivores (e.g., Grasshoppers, zooplankton). The number of primary carnivores (e.g., frogs, smaller fish) is still smaller. The number of higher order carnivores is very small (Fig. 14.13).

However, if the producer is large-sized like a tree, the pyramid of numbers can be inverted or spindle-shaped. A tree may support many herbivorous birds that may carry a large number of parasites or feed one or two hawks (Fig. 14.14).

Pyramid of Biomass (Definition as in text). Pyramid of biomass is generally upright with maximum biomass present in producers followed by lesser biomass in herbivores and still small biomass in carnivores. Only 10-20% biomass is transferred from lower trophic to its higher trophic level (Fig. 14.16).

However, inverted or spindle-shaped pyramid of biomass is found in aquatic habitats due to smaller biomass of phytoplankton at any time because its members have a short life span but very high reproductive potential (Fig. 14.18).

8. Define decomposition and describe the processes and products of decomposition.

✓ **Definition.** Refer to the text.

Processes and Products. Three categories of processes operate simultaneously — fragmentation, catabolism and leaching.

1. **Fragmentation.** It is carried out by detritivores (e.g., earthworms, termites). Detritivores break the detritus. Fine fragments are left out while the other ones are ingested. Their faecal matter also contains a lot of pulverised detritus.

2. **Catabolism.** Saptrophs or decomposers (mostly bacteria and fungi) pour their digestive enzymes over the fragmented detritus. This causes breakdown and solubilisation of a number of organic substances. Some substances are however, slow to be decomposed, e.g., lignin, cellulose. As a result detritus is converted into **humus**. The process is called **humification**. Humus degrades slowly and is ultimately decomposed completely. Decomposition of organic matter releases inorganic substances. The process is known as **mineralisation**. Inorganic substances become available for absorption and utilisation by plants.

3. **Leaching.** Soluble substances formed during decomposition pass into soil along with percolating water to be made available to roots of plants for absorption.

9. Give an account of energy flow in an ecosystem.

✓ Energy flow is input of energy in an ecosystem and its passage through various trophic levels. Energy flow is unidirectional as it is partially dissipated at all the steps of its transfer and transformation. (Fig. 14.11).

Input of Energy. About 1-5% of incident solar energy or 2-10% of PAR is trapped by producers to form organic matter. About 20% of this stored energy is utilised by producers in their respiration. The remaining called net primary productivity is available to the rest of the ecosystem.

Passage to Herbivores. Herbivores feed on plants. Along with organic matter or food, its contained energy becomes available to herbivores. However, only about 10% of energy is stored in herbivore biomass. The remaining is lost to decomposers or waste organic matter or dissipated as heat.

Passage to First Order Carnivores. Herbivore biomass is available to first order carnivores or primary carnivores for predation. However, only about 10% of herbivore biomass energy is used for body building by primary carnivores. The remaining is dissipated as heat or lost to decomposers.

Passage to Higher Order Carnivores. First order carnivores are preyed upon by second order carnivores while the latter are devoured by third order carnivores, if any. Along with food, its contained energy passes in the synthesis of higher order carnivore biomass. The amount is only 10% of the energy present at the lower level.

Energy to Decomposers. Energy contained in the waste organic matter is partly dissipated and partly passed into detritivores and decomposers. However, it is ultimately lost from ecosystem components. Therefore, a regular input of energy is required for maintaining the various components of the ecosystem.

10. Write important features of sedimentary cycle in ecosystem ?

✓ It is circulation of nongaseous biogenetic nutrient between abiotic and biotic components of ecosystem with reservoir pool being lithosphere and cycling pool being soil (for terrestrial ecosystem) or water (for aquatic ecosystem). It consists of three steps — input, internal cycling and output.

Input. Weathering of rocks regularly adds small quantity of the nutrient into the cycling pool. Mining and industrial processing may also add the nutrient to the cycling pool.

Internal Cycling. Nutrient present in the cycling pool is picked up by producers and made part of the organic substances. It is called **uptake**. Organic matter containing the nutrient passes into higher trophic levels. It is called **transfer**. Wastes and dead bodies of organisms give rise to **detritus**. Detritus undergoes decomposition. The nutrient locked in the organic matter is released in the process of **mineralisation**. It replenishes the cycling pool. It is, however, seldom complete as some nutrient passes out of the cycling pool.

Output. It is loss of nutrient from the cycling pool. Output occurs due to run off, soil erosion, removal of wood and litter, grazing, harvesting of crops, etc.

11. Outline the salient features of carbon cycling in an ecosystem.

✓ Carbon cycle is the circulation of carbon between the abiotic and biotic components of the ecosystem with reservoir pool being carbonate rocks while the cycling pool consists of atmosphere and hydrosphere.

Input. Carbon is being added to the cycling pool regularly by combustion of fossil fuels, respiration of organisms, volcano eruptions, hot springs, methane chimneys, weathering of carbonate rocks and industrial processing.

Internal Cycling. Carbon present in the atmosphere (as CO_2) and hydrosphere (as bicarbonate and carbonic acid) is picked up by producers and changed into organic compounds in the process of photosynthesis. Annual carbon fixation is about 4×10^{13} kg. It produces about 170 billion tonnes (17×10^{13}) of organic matter. Withdrawal of carbon by producers is called **uptake**. Part of organic matter synthesized by producers passes into higher trophic levels (herbivores, carnivores). It is called **transfer**. Wastes and dead bodies of organisms form **detritus**. Detritus is degraded by

decomposers to release carbon locked in it. It enters the cycling pool for re-use by producers.

Output. Some carbon is being taken out of cycling pool due to seepage of carbon rich water into interior of earth, skeletons and shells of animals and fossilisation.

12. Distinguish between the following: (a) Grazing food chain and detritus food chain (b) Productivity and decomposition (c) Upright and Inverted pyramid (d) Food chain and food web. (e) Litter and detritus (f) Primary and secondary productivity.

✓ Refer to the text.

13. What is primary productivity ? Give brief description of factors that affect primary productivity ?

✓ Definition. Refer to the text.

Factors Affecting Primary Productivity. Refer to the text.

TEXT QUESTIONS

One Mark Questions (With Answers)

- Why producers are also named transducers ?
cause they are able to change radiant or light energy into chemical form.
- What is eltonian pyramid ?
✓ Eltonian pyramid or ecological pyramid is graphic representation of an ecological parameter (like number of individuals, biomass or energy) present in various trophic levels of a food chain with producers forming the base and carnivores the top.
- How deep in sea, producers are present ?
✓ Up to 200 m.
- Which organisms constitute the last trophic level ?
✓ Decomposers.
- What are biogenetic nutrients ?
✓ They are inorganic substances provided by earth which are required by organisms for their body building and metabolism.
- Define biomass ?
✓ Biomass is the amount of living material or organic matter present in an organism, community or biome.
- Define a sere ?
✓ The entire sequence of development stages of biotic succession from pioneer to a climax community is known as sere.
- How much time is taken by a primary succession to complete ?
✓ It is often 1000 years or more.
- Which species can be named as dominant species ?
✓ Dominant species is that species which represent most numerous population in a seral or climax community.

One Mark Questions (Without Answers)

- Define hydrosere.
- What is ecosystem ? Who coined the term ?
- Name an anthropogenic ecosystem.
- Name the two basic components of ecosystem.
- What do you mean by abiotic components of ecosystem ? Name five of them.
- What are phytoplanktons and macrophytes ?
- Define (a) Herbivore (b) Carnivore (c) Top carnivore.
- What do you mean by standing crop and standing state ?
- Define detritus. Is it biotic or abiotic component of ecosystem ?
- Define the terms humus, humification and mineralisation.
- What do you mean by nutrient immobilisation ?
- What is food chain ?

22. Write one difference between net primary productivity and gross primary productivity. (CBSE 2011)
23. Write the equation that helps in deriving net primary productivity of an ecosystem. (CBSE 2013)
24. State what does "standing crop" of a trophic level represent. (CBSE 2013)
25. What is detritus food chain made up of? How do they meet their energy and nutritional requirements? (CBSE 2013)
26. "Man can be primary as well as secondary consumer". Justify this statement. (CBSE 2015)

Two Mark Questions (With Sample Answers)

1. Name the edaphic factors of an ecosystem?
✓ The edaphic factors include those connected with soil or substratum like topography, background, mineral elements, pH, etc.
2. How light affects pigmentation of biotic components of an ecosystem?
✓ In strong light yellow and red tints appear on the leaves. Moderate light forms bright green leaves. Intensity of light changes skin colour in human beings as well as in several animals. Wall lizard and frog are light coloured when kept in bright light. They become dark coloured in dim light. Some mammals and birds have seasonal colour changes. Snow Hare develops white colour during autumn.
3. Name the type of food chains responsible for the flow of larger fraction of energy in an aquatic and a terrestrial ecosystem respectively. Mention one difference between the two food chains. (CBSE 2010)
4. List the features that make a stable biological community. (CBSE 2010)
5. Identify the type of given ecological pyramid and give one example each of pyramid of number and pyramid of biomass in such cases. (CBSE 2011)
6. Why is the pyramid of energy always upright? Explain. (CBSE 2013)
7. "It is possible that a species may occupy more than one trophic level in the same ecosystem at the same time"? Explain with the help of one example. (CBSE 2013)
8. Apart from being part of food chain, predators play other important roles. Mention any two such roles supported by examples. (CBSE 2014)
9. How are productivity, gross productivity, net primary productivity and secondary productivity inter-related. (CBSE 2015)

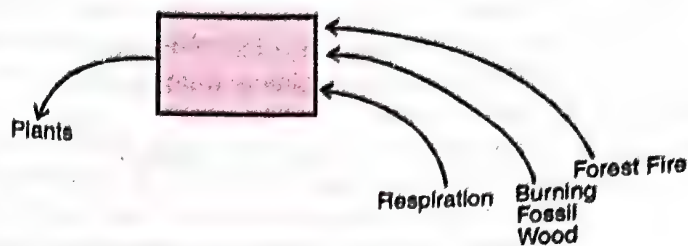
Three Mark Questions (Short Answer type)

1. Construct an ideal pyramid of energy when 1,000,000 joules of sunlight is available. Label all its trophic levels. (CBSE 2009)
2. What is primary productivity? Give brief description of factors that affect primary productivity.
3. Why are herbivores considered similar to predators in the ecological context? Explain. (CBSE 2010)
4. (a) What is primary productivity? Why does it vary in different types of ecosystems? (CBSE 2014)
5. State the function of a reservoir in a nutrient cycle. Explain the simplified model of carbon cycle in nature. (CBSE 2014)
6. Justify the importance of decomposers in an ecosystem. (CBSE 2015)
7. Why is earthworm considered a farmer's friend? Explain humification and mineralisation occurring in a decomposition cycle. (CBSE 2015)
8. (a) State any two differences between phosphorus and carbon cycle in nature.
(b) Write the importance of phosphorus in living organisms. (CBSE 2015)
9. (a) Construct a pyramid of number by taking suitable examples for each trophic level in an ecosystem.
(b) Explain why a progressive decline is seen in the population size from the first to fourth trophic level in the above pyramid. (CBSE 2015)
10. "In a food chain, a trophic level represents a functional level, not a species." Explain. (CBSE 2016)
11. Differentiate between primary and secondary succession. Provide one example of each. (CBSE 2016)
12. Describe the inter-relationship between productivity, gross primary productivity and net productivity. (CBSE 2017)

Five Mark Questions (Long Answers Type)

1. Describe the process of decomposition of detritus under the following heads. Fragmentation, Leaching, Catabolism, Humification and Mineralisation. (CBSE 2010)
2. (a) Trace the succession of plants on a dry bare rock.

- (b) How does phosphorus cycle differ from carbon cycle ? (CBSE 2010)
3. (a) Explain primary productivity and the factors that influence it.
(b) Describe how do oxygen and chemical composition of detritus control decomposition. (CBSE 2011)
4. (i) Name the biogeochemical (nutrient) cycle shown above. (ii) Name an activity of the living organisms not depicted in the cycle by which this nutrient is returned to the atmosphere.
(b) How would the flow of the nutrient in the cycle be affected due to large scale deforestation? Explain giving reasons.
(c) Describe the effect of an increased level of this nutrient in the atmosphere on our environment. (CBSE 2011)
5. (a) Healthy ecosystems are the base of wide range of ecosystem services. Justify.
(b) Explain the differences and similarities between hydrarch and xerarch succession of plants. (CBSE 2011)
6. (a) Explain the significance of ecological pyramids with the help of an example.
(b) Why are the pyramids referred to as 'upright' or 'inverted'. Explain. (CBSE 2012)
7. "It is often said that the pyramid of energy is always upright. On the other hand, the pyramid of biomass can be both upright and inverted". Explain with the help of examples and sketches. (CBSE 2015)
8. Describe the advantage of keeping the ecosystem healthy ? (CBSE 2015)
9. (a) Taking an example of a small pond, explain how the four components of an ecosystem function as a unit.
(b) Name the type of food chain that exists in a pond. (CBSE 2016)



Value Based Question

1. What are ecosystem services? What lessons do they give to human society ?
✓ Ecosystem processes and products that have a direct or indirect role in maintaining the balance of nature, protecting the various components of biosphere and providing resources to wildlife, tribals and other humans are called ecosystem services. Four of these services are : (i) **Carbon Fixation**. Manufacture of food in photosynthesis results in absorption of CO_2 by plants and maintaining its level in atmosphere. The process provides food to all organisms including tribals, grazing animals and several useful products to industries. (ii) **Oxygen Release**. During carbon fixation plants release oxygen. The process replenishes the gas being consumed in respiration and combustion. (iii) **Pollination**. A number of insects and other animals are engaged in pollination of plants. They obtain food in return. (iv) **Seed Dispersal**. Several plants disperse their seeds with the help of animals. The animals are rewarded with food.
- Lesson.** Ecosystems are self contained systems with intricate inter-relationship which should not be disturbed as they are likely to affect the balance of nature and the services they provide. Already, destruction of several forests in the past has resulted in rise of CO_2 concentration, increased floods and desertification of large tracts.
2. Why is food web more stable than food chain? What lesson does it give to us?
✓ Food web is a network of food chains which are inter-connected at various trophic levels so as to form a number of feeding connections amongst members of a biotic community. Food chain is a linear sequence of organisms through which food and its contained energy passes, with earlier member of the sequence becoming food of the later member of the sequence. A secluded food chain is always at a risk of being damaged with a major effect on the ecosystem as well. Suppose tiger population increases. Its prey population of say deer will decrease rapidly resulting in the nonavailability of food to tigers, their starvation and hence death. However, in a food web, each predator has a choice to feed on different types of preys. Reduction in population of one type of prey will not affect the predator because it can switch over to postulate on some other animals. Meanwhile, the population of preferred prey recovers.
- The concept of food web or nondependence on a single source or aim is very valid for energy body. Suppose you are a manufacturer. Supply of raw materials as well as sale of products must be to many parties if you do not want any disruption. You want to be a computer engineer but cannot get

grade to obtain admission. Switching over to another stream will save you from desperation and depression.

3. Why is India surplus in food grains though its output is lower than that of deficient Russia. What value does it depict?

✓ Russians are nonvegetarians while a large section of Indian population is vegetarian. As per 10% law one kilogram of meat requires ten kilogram of vegetarian diet. Therefore, the requirement of feeding the meat yielding animals surpasses the requirement of direct feeding of vegetarian food to human beings.

The problem of food shortages can be solved almost immediately if most of human population becomes vegetarian. The concept that meat yields more energy is erroneous. The requirement of protein by adults is not much. Even for young individuals, milk and its preparations can provide the required protein. Pulses and other plant foods are also a good source of proteins.

Multiple Choice Questions

- (1) Which pair is mismatched ?
(a) Tundra — Permafrost (b) Savanna — *Acacia* trees (c) Prairie — epiphytes (d) Coniferous forest — evergreen trees. (CBSE 2005)
- (2) Lichen is pioneer in succession
(a) Hydrosere (b) Lithosere (c) Psammosere (d) Xerosere. (BHU 2006)
- (3) Detritus food chain begins with (a) virus (b) bacteria (c) protozoa (d) algae. (Orissa 2007)
- (4) Highest net annual productivity occurs in
(a) Tropical rain forests (b) Tropical deciduous forests (c) Temperate evergreen forests (d) Temperate deciduous forests. (CBSE 2007)
- (5) Which one shows detritus food chain
(a) Grass → Insects → Snakes (b) Plankton → Small fish → Large fish (c) Organic wastes → Bacteria → Molluscs (d) All the above (DPMT 2008)
- (6) Which has the highest value in a grassland (a) net production (b) gross production (c) secondary production (d) tertiary production. (AFMC 2008)
- (7) Slow rate of decomposition of fallen logs is due to (a) poor nitrogen content (b) anaerobic environment (c) low cellulose contents (d) low moisture contents. (CBSE 2008)
- (8) Pick up the correct statements (i) removal of 80% tigers resulted in greatly increased growth of vegetation (ii) removal of most carnivores resulted in increased population of deer (iii) length of food chain is generally limited to 3-4 trophic levels due to energy loss (iv) length of food chain may vary from 2-8 trophic levels. (a) i, ii (b) ii, iii (c) iii, iv (d) i, iv. (CBSE 2008)
- (9) Trophic levels in ecosystem are formed by
(a) only bacteria (b) only plants (c) only herbivores (d) organisms linked in food chain. (W. B. 2009)
- (10) Which one occupies more than one trophic level in a pond ecosystem
(a) Zooplankton (b) Phytoplankton (c) Fish (d) Frog. (CBSE 2009)
- (11) Highest plant productivity occurs in
(a) Desert (b) Temperate grassland (c) Tropical rain forest (d) Tundra. (DPMT 2010)
- (12) Biomass available for consumption by herbivores and decomposers is called
(a) secondary productivity (b) standing crop (c) gross primary productivity (d) net primary productivity. (CBSE 2010)
- (13) Mass of living matter at a trophic level in an area at any time is called
(a) Humus (b) Standing state (c) Standing crop (d) Detritus. (CBSE 2011)
- (14) The breakdown of detritus into small particles by earthworm is a process called
(a) Mineralisation (b) Catabolism (c) Humification (d) Fragmentation. (CBSE Mains 2011)
- (15) *Pheretima* and its close relatives obtain nourishment from (a) soil insects (b) small pieces of fresh fallen leaves (c) decaying fallen leaves and soil organic matter (d) Sugarcane roots. (CBSE 2012)
- (16) The second stage of hydrosere is occupied by plants like (a) *Azolla* (b) *Salix* (c) *Typha* (d) *Vallisneria*. (CBSE Mains 2012)
- (17) Natural reservoir of phosphorus is (a) Fossils (b) Sea water (c) Animal bones (d) Rocks. (NEET 2013)
- (18) Secondary productivity is rate of formation of new organic matter by (a) Decomposers (b) Producers (c) Parasite (d) Consumer. (NEET 2013)

- (19) Breakdown of detritus into small particles by detritivores is called
(a) Fragmentation (b) Humification (c) Catabolism (d) Mineralisation (e) Leaching. (Kerala 2014)
- (20) Gross primary productivity is the rate of production of _____ during photosynthesis (a) organic matter (b) oxygen (c) carbon dioxide (d) chlorophyll. (MHT CET 2014)
- (21) For sedimentary type of biogeochemical cycles, the reservoir is (a) atmosphere (b) water (c) earth's crust (d) living organisms. (COMED-K 2015)
- (22) The term ecosystem was coined by (a) Warming (b) Odum (c) Tansley (d) Haeckel. (NEET-I 2016)
- (23) A system of rotating crops with legume or grass pasture to improve soil structure and fertility is called (a) shifting agriculture (b) ley farming (c) contour farming (d) strip farming. (NEET-I 2016)
- (24) Which ecosystem has the maximum biomass (a) Forest ecosystem (b) Grassland ecosystem (c) Pond ecosystem (d) Lake ecosystem. (NEET 2017)

Assertion Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—

- (a) If both A and R are true and R is the correct explanation of A
(b) If both A and R are true and R is not the correct explanation of A
(c) If A is true but R is false
(d) If both A and R are false.

- Assertion:** shallow water rooted plants are called phytoplankton.
Reason: They are the dominant producers in shallow waters.
A B C D
- Assertion:** The amount of minerals present in the soil is called standing crop.
Reason: The growth of plants depends upon the amount of minerals available from soil.
A B C D
- Assertion:** Decomposition of detritus helps in biogeochemical cycling.
Reason: Humus formed during decomposition slowly releases the minerals in the process of mineralisation.
A B C D
- Assertion:** Net primary productivity is less than the gross primary productivity.
Reason: Only a part of incident energy is utilised in photosynthesis.
A B C D
- Assertion:** Herbivore productivity is approximately 10% of gross productivity of producers.
Reason: Herbivores eat less and waste a lot of food energy.
A B C D
- Assertion:** Pyramid of biomass is inverted in aquatic ecosystem.
Reason: Longevity increases with the rise in trophic levels.
A B C D
- Assertion:** Primary succession occurs in a freshly harvested field.
Reason: Succession occurs over a bare area.
A B C D
- Assertion:** Reed Swamp stage of hydrosere occurs in shallow water.
Reason: The stage is characterised by the presence of amphibious plants.
A B C D
- Assertion:** A network of food chains existing together in an ecosystem is known as food web.
Reason: An animal like Kite cannot be part of food web. (AIIMS 2006)
A B C D
- Assertion:** A network of food chains of an ecosystem is called food web.
Reason: Kite cannot be part of food web. (AIIMS 2008)
A B C D
- Assertion:** In a terrestrial ecosystem, detritus food chain is a major conduit for energy flow.
Reason: Solar energy is direct source of energy supply in detritus food chain. (AIIMS 2012)
A B C D
- Assertion:** Rice field is an ecosystem for plants and animals.
Reason: Gut of humans/animals is an ecosystem for flora and fauna. (AIIMS 2013)
A B C D

ANSWERS**Multiple Choice Questions**

(1) —a (2) —b (3) —b (4) —a (5) —c (6) —b (7) —d (8) —b (9) —d (10) —c
(11) —c (12) —d (13) —c (14) —d (15) —c (16) —d (17) —d (18) —d (19) —a (20) —a
(21) —c (22) —c (23) —b (24) —a

Assertion Type Questions

(1) —D (2) —D (3) —A (4) —B (5) —C (6) —A (7) —D (8) —A (9) —C (10) —C
(11) —C (12) —B

Biodiversity (Gk. *bios*– life, *diversity*– forms; Rosen, 1985) or biological diversity is the occurrence of different types of ecosystems, different species of organisms with the whole range of their variants (biotypes) and genes adapted to different climates, environments along with their interactions and processes. The term biodiversity was popularised by sociobiologist Edward Wilson (1992). The degree of biodiversity is quite staggering. There are some 20,000 species of ants alone, 3,00,000 species of beetles, 28,000 species of fishes and 20,000 species of orchids. It is very difficult to understand why are there so many species of a single type of organisms like ants or beetles. How has this diversification appeared in nature? Was it present all the time or is it only of recent origin? Is this biodiversity useful to humans? What is its importance to biosphere? What harm would it cause to biosphere and human interests if the biodiversity is reduced?

Magnitude of Biodiversity

IUCN (2004) has put the total number of known plant and animal species to slightly more than 1.5 million. Taxonomists place the number slightly higher. The number of higher plants known to science is 2,70,000, vertebrates 53239, insects 1,025,000, fungi 72,000, molluscs 70,000, algae 40,000, crustaceans 43,000, protozoans 40,000, nematodes and worms 25,000, bacteria 4000, viruses 1550 with other groups accounting for 110,000 species. This totals some 17,53,739 (1.75 million) species. Out of these the number of known species in India is 1,42,000 or roughly 8.1% of the total though India has only 2.4% land area. India with about 45000 species of plants and twice as many species of animals is one of the 17 megadiversity countries of the world. However, the predicted number of species is very large. It is believed that a very large number of species are yet to be discovered. The major area where numerous species are believed to be unknown to science are tropics and coral reefs. Scientists estimate the number of species present in tropics by comparing species richness between tropics and temperate areas. For most groups of organisms, inventories are nearly complete for temperate areas. Estimates are made of their number in tropics on the basis of temperate-tropical species richness of some exhaustively studied groups. On this basis, scientists have calculated that the total number of species in the world is anywhere between 5 and 50 million. Robert May places the number at 7 million. It seems to be more conservative and scientifically sound estimate.

The most intriguing question of biodiversity is that more than 70% of all species are animals while plants account for only 22%. Amongst animals, insects are the most numerous (about 70%) with previous estimate of 7 out of 10 and present estimate of 8 out of 10 animals. Further the knowledge about protists, archaea, bacteria and viruses is quite fragmentary. The problem is that conventional taxonomic methods are not suited for identification and characterisation of microbial species. Even some species cannot be cultured under laboratory conditions. If chemical or molecular criteria are employed for distinguishing species, the diversity of microbes will run into millions.

New species are being discovered faster than 15000/yr due to projects like Global Biodiversity Information Facility and Species 2000. However, the task is stupendous. If May's proposal for discovery of new species is accepted, the number of new plant and animal species to be discovered in India alone would be more than 1,00,000 plants and 3,00,000 animals. It requires a large trained manpower of taxonomists and a lot of time. However, a very large number of new species that are yet to be discovered are becoming extinct due to large scale destruction of forests and other natural ecosystems.

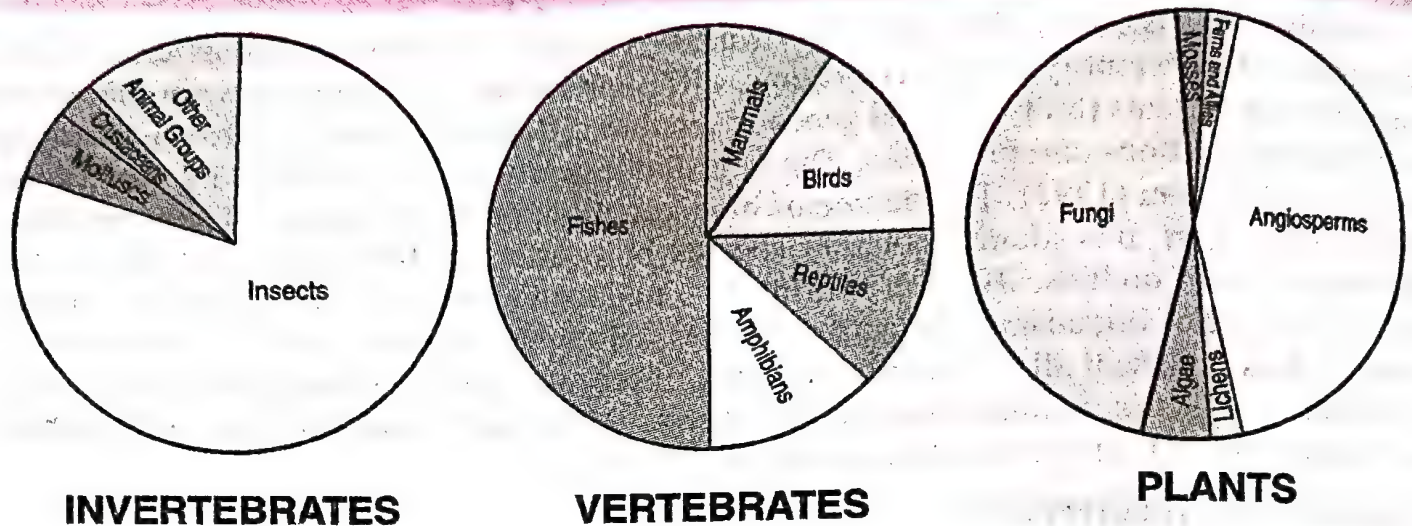


Fig. 15.1. Global biodiversity : the species number of invertebrates, vertebrates and major taxa of plants.

Table 15.1. Number of Identified Species in the World			Table 15.2. Number of Species in India		
1.	Higher Plants	2,70,000	1.	Angiosperms	17,500
2.	Algae	40,000	2.	Gymnosperms	64
3.	Fungi	72,000	3.	Pteridophyta	1,100
4.	Bacteria/Cyanobacteria	4,000	4.	Bryophyta	2,850
5.	Viruses	1,550	5.	Lichens	2,000
6.	Mammals	4,650	6.	Fungi	14,500
7.	Birds	9,700	7.	Algae	6,500
8.	Reptiles	7,150	8.	Bacteria	850
9.	Fish	26,959	9.	Mammals	300
10.	Amphibians	4,780	10.	Birds	1,232
11.	Insects	10,25,000	11.	Reptiles	456
12.	Crustaceans	43,000	12.	Amphibians	209
13.	Molluscs	70,000	13.	Fish	2,546
14.	Nematodes and Worms	25,000	14.	Protochordates	119
15.	Protozoa	40,000	15.	Arthropods	68,389
16.	Others	1,10,000	16.	Molluscs	5,070
			17.	Protozoan	2,577
			18.	Other Invertebrates	8,329

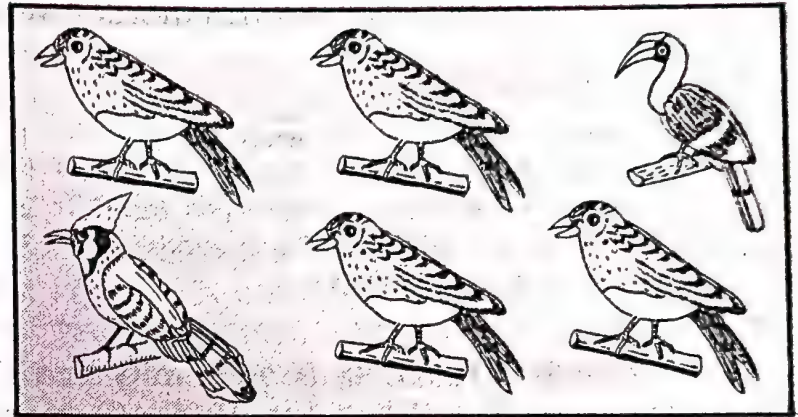
Levels of Biodiversity

The term biodiversity was applied by sociobiologist Edward Wilson (1992) to describe diversity at all levels of biological organisation ranging from macromolecules inside the cells

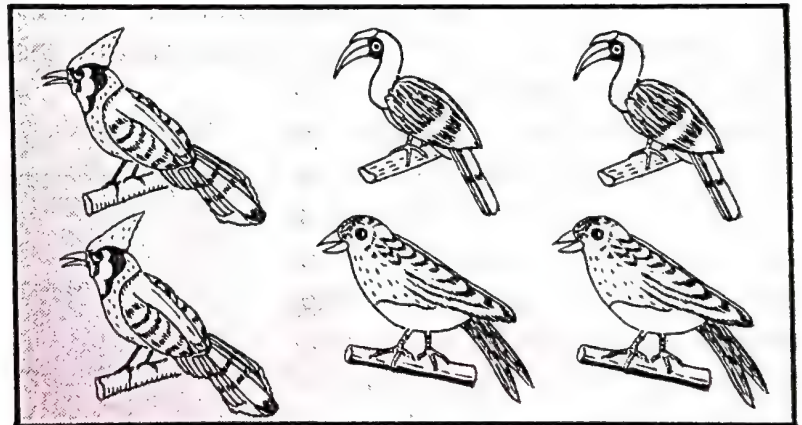
to biomes. It is of three inter-related hierarchical levels—genetic diversity, species diversity and community/ecosystem diversity.

1. Genetic Diversity. It is the diversity in the number and types of genes as well as chromosomes present in different species and the variations in the genes and their alleles in the same species. On the average a bacteriophage has 100 genes, mycoplasma 450–700 genes, *Escherichia coli* 4000 genes, *Saccharomyces cerevisiae* 6000 genes, *Drosophila melanogaster* 13,000 genes, *Coenorhabditis elegans* 18,000 genes, *Oryza sativum* 32,000–50,000 genes and *Homo sapiens* 30,000–40,000 genes. Variations in the genes of a species increase with increase in size and environmental parameters of the habitat. It results in formation of **polymorphs**—ecotypes, races, varieties and subspecies. Genetic diversity is useful in adaptation to changes in environmental conditions. Medicinal plants, *Rauwolfia vomitoria* (= *R. serpentina*), growing in different Himalayan ranges, shows differences in the potency and concentration of active chemical called **reserpine** due to genetic diversity. Human beings have exploited this genetic diversity in raising numerous varieties of domesticated plants and animals. India has more than 50,000 genetically diverse varieties of Rice and 1000 varieties of Mango. Genetic diversity also helps in **speciation** or evolution of new species. Lower genetic diversity within a species or variety may be useful for uniformity in yield as well as higher yield. However, it is liable to undergo degradation and prone to mass scale destruction at the hands of fungal or insect attacks.

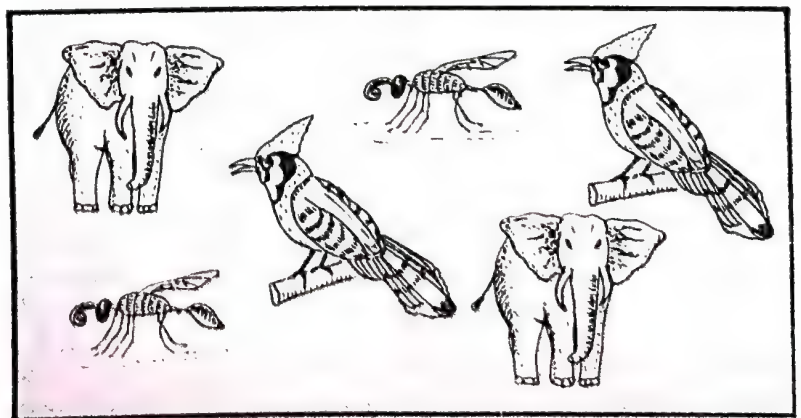
2. Species Diversity. Western Ghats have greater amphibian species diversity as compared to Eastern Ghats. Species diversity is the variety in the number and richness of the species of a region. The number of species per unit area is called **species richness**. Number of individuals of different species represent **species evenness** or **species equitability**. Communities where species are represented by more or less equal number of individuals exhibit **evenness**. Others where one or more species have more individuals than others show **dominance** or unevenness.



SAMPLE AREA 1



SAMPLE AREA 2



SAMPLE AREA 3

Fig. 15.2. Species Richness.

A, Related uneven (less diversity). B, Related even (more diversity). C, Unrelated even (higher diversity).

Species diversity is product of both species richness and evenness or equitability, i.e., species richness weighed by species evenness. A community having three different bird species represented by 4, 1 and 1 individuals is less diverse than the community having three bird species with two individuals of each species (highest evenness). Still more diverse will be community having three species of different taxonomic groups (e.g., ant, bird, elephant) represented by equal number of individuals (Fig. 15.2). Odum *et al* (1960) calculate species diversity (d) as number of species per thousand individuals while Menhinick (1964) calculates it as number of species in relation to square root of total number of individuals. Diversity index commonly used in ecological studies is **Shannon index**.

Differences between Genetic Diversity and Species Diversity

Genetic Diversity	Species Diversity
<ol style="list-style-type: none"> 1. It is related to number of genes and their alleles found in organisms. 2. It is trait of the species. 3. It influences adaptability and distribution of a species in diverse habitats. 	<ol style="list-style-type: none"> 1. It is related to number and distribution of species found in an area. 2. It is trait of the community. 3. It influences biotic interactions and stability of the community.

3. **Ecological Diversity (Community and Ecosystem Diversity, Fig. 15.3).** It is of three types— α , β , γ (Whittaker, 1965). (i) **Alpha Diversity (α -index Diversity, Within-Community Diversity).** It is a species diversity in a given community or habitat. α -diversity is dependent upon species richness and evenness/equitability. There is a lot of competition, adjustments and interrelationships amongst members of the same community. Variations are limited. (ii) **Beta Diversity (β -index Diversity between Community Diversity).** It is biodiversity which appears in a range of communities due to replacement of species with the change in community/habitat due to presence of different micro-habitats, niches and difference in environmental conditions. (iii) **Gamma Diversity (γ -index Diversity).** It is diversity present in ranges of communities as represented by diversity of habitats/ecosystems over a total landscape or geographical area. Ecosystem diversity is quite high in India because of the occurrence of a large number of ecosystems like deserts, rain forests, deciduous forests, mangroves, coral reefs, wetlands, estuaries and alpine meadows. It is quite low in small countries like Norway.

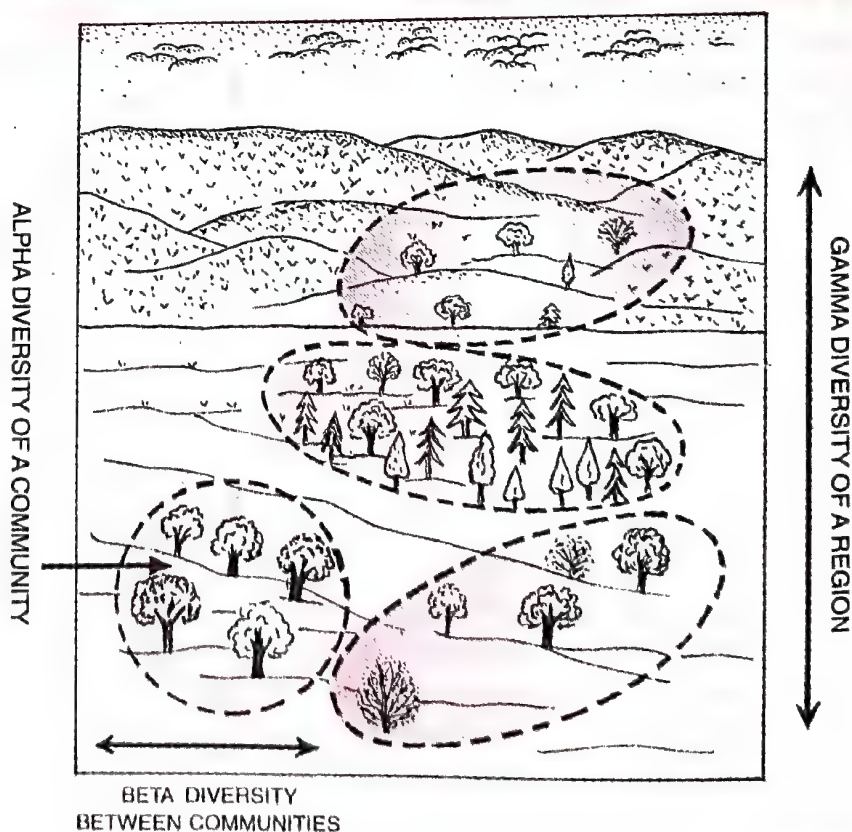


Fig. 15.3. Three types of diversity.

Ecosystem diversity is the variety of forms in the ecosystem due to diversity of niches, trophic levels and ecological processes like nutrient recycling, food webs, energy flow, role of dominant species and keystone species and various biotic interactions. Diversity helps in producing more productive and stable ecosystems/communities which can tolerate various stresses like prolonged drought (Elton 1958). It was confirmed experimentally by Tilman (1990) by raising plots with different diversities in Minnesota grassland and subjecting them to various stresses.

Diversity is not achieved within a few years. It takes million of years of evolution to create the same. Indiscriminate deforestation and habitat destruction will result in complete loss of biodiversity wealth in less than two centuries. This will make our planet vulnerable to all types of catastrophes. Therefore, more and more people are realising the importance of biodiversity, its protection and maintenance.

Biogeographic Regions of India (India's Biodiversity—Fig. 15.4)

India is one of the seventeen megadiversity regions of the world with 8.1% of genetic resources of the world. Wildlife Institute of India has divided the country into ten biogeographical regions— 1. Trans-Himalayas, 2. Himalayas, 3. Desert, 4. Semi-arid, 5. Western Ghats, 6. Deccan Peninsula, 7. Gangetic Plain, 8. North East, 9. Coasts, 10. Islands. The largest biogeographical region is Deccan Peninsula which occupies 42% land mass of the country. The most biodiversity rich regions are Western Ghats (area 4.0%) and North-East (area 5.2%). Trans-Himalayas is cold desert with sparse vegetation. It has a rich community

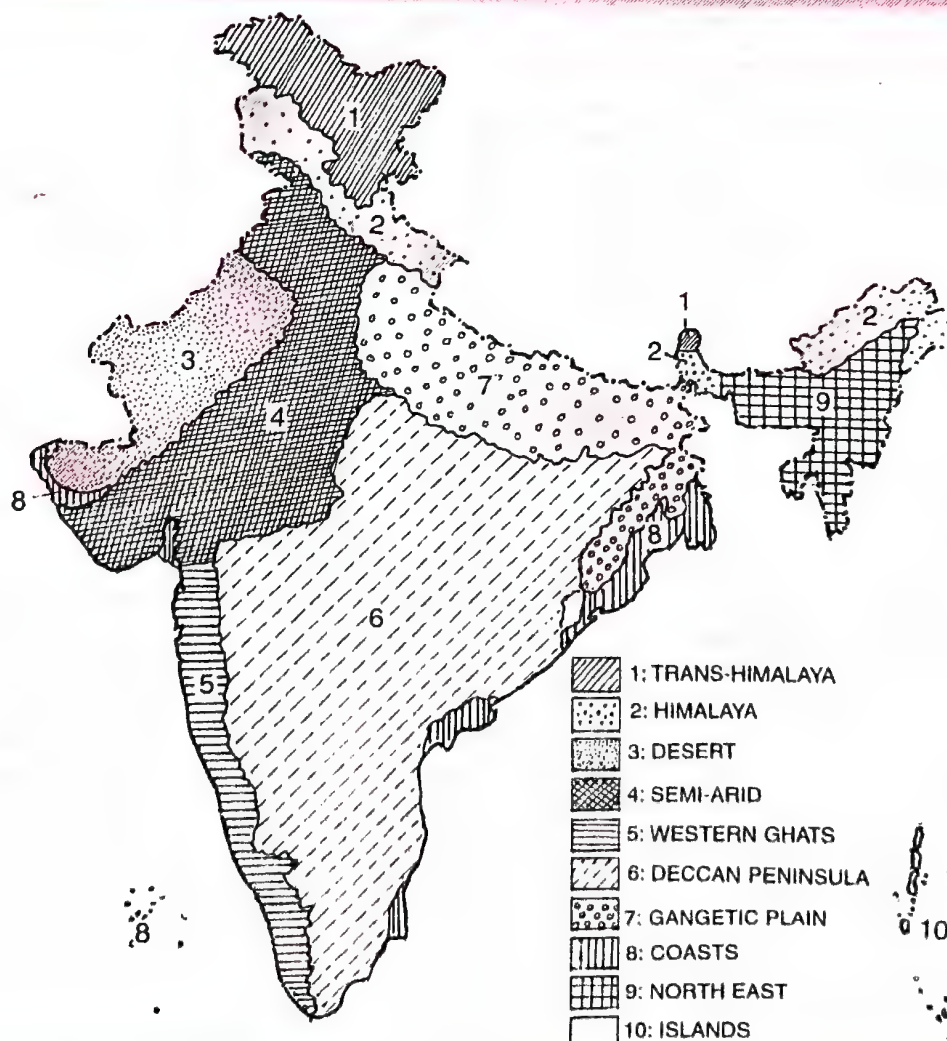


Fig 15.4. Biogeographical regions of India.

of Goat and Wild Sheep besides Snow Leopard. North-East and Western Ghats have wild relatives of number of cultivated plants like Banana, Citrus, Mango, Pepper, etc. Very good evergreen forests occur in islands of Andaman Nicobar and Lakshadweep. Mangrove vegetation is found in swamps along the coasts, e.g., Sunderbans, Ratnagiri, Pichavaram. 33% of flowering plants, 10% of mammals, 36% reptiles, 60% amphibians and 53% fresh water fish are **endemic** (restricted to a particular area or region). Most of the endemics occur in North-East, North-West, Western Ghats, Andaman Nicobar islands. Western Ghats possess a very large number of endemic amphibian species. However, we are yet to unveil the vast biodiversity of many ecosystems like wetlands, lakes, deep oceans, tree canopy and soil of tropical forests.

Generation of Biodiversity

According to Reice (1994) more biodiversity is generated where there are more perturbations and heterogeneity. Tropical rain forests and coral reefs have fragile environment and vulnerable habitats so that they have the maximum biodiversity despite having little seasonal changes of temperature and moisture. Very harsh conditions, however, bring about reduction in biodiversity.

Patterns of Biodiversity

(1) **Latitudinal and Altitudinal Gradients.** Barring arid/semiarid and aquatic habitats, biodiversity shows latitudinal and altitudinal gradients also called **master gradients**. There is little biodiversity at the poles. It increases in temperate areas but reaches the maximum in tropics (23.5° N to 23.5° S). It is because the tropical rain forests have favourable environmental conditions not only for speciation but also for supporting both variety and number of organisms. Harsh conditions exist in temperate areas during the cold season only while very harsh conditions prevail for most of the year in arctic regions. Number of vascular species is 118–236/0.1 ha in tropical forests and 21–48 species/0.1 ha in temperate forests. Their number would be 0.0–10.0 in arctic regions. Such a correlation occurs also in case of other taxonomic groups like ants (Fig. 15.5.) butterflies, moths, birds, etc.

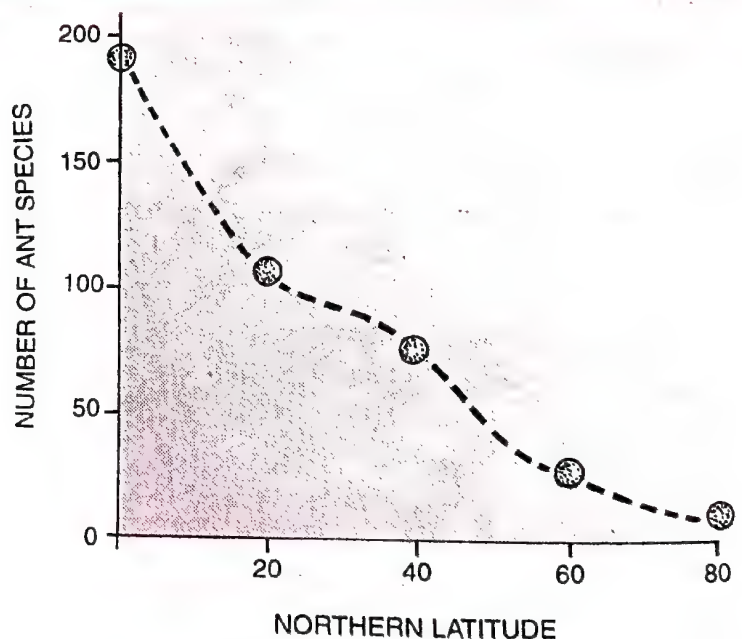


Fig. 15.5. Change in diversity of ant species with change in latitude.

Columbia located near equator has about 1400 species of birds, New York (41° N) has 105 species while Greenland (71° N) has only 56 species. India with most land in tropical zone, has over 1200 species of birds. Similarly, tropical area like Ecuador contains 10 times more vascular plants as compared to temperate region like midwest of U.S.A. **Maximum diversity** occurs in tropical Amazon rain forest of South America with 40,000 species of plants, 3000 species of fish, 1300 birds, 427 mammals, 427 amphibians, 378 reptiles and more than 1,25,000 invertebrates. The rain forests might have upto two million insect species yet to be discovered and named.

A decrease in species diversity occurs as we ascend a high mountain due to (Fig. 15.5.)

drop in temperature (lapse temperature being 6.5°C for 1km or 1000m) and greater seasonal variability. It should not be confused with complexity and heterogeneity of the physical environment which tends to increase complexity and diversity of flora and fauna of an area.

There are various hypotheses for higher diversity in tropical areas. (i) Speciation is a function of time. Temperate areas have undergone frequent glaciation in the past. It killed most of the species. No such disturbance occurred in tropics where species continued to flourish and evolve undisturbed for millions of years. (ii) There are no unfavourable seasons in tropics. Continued favourable environment has helped tropical organisms to gain more niche specialisation and increased diversity. (iii) More solar energy is available in tropics. This promotes higher productivity and increased biodiversity. (iv) Resource availability is higher in tropics. (v) There is reduced competition in tropics due to favourable environment. (vi) Rate of extinction is low in tropics.

(2) **Species-Area relationships** (Fig. 15.6). German naturalist and geographer Alexander von Humboldt while exploring the wilderness of South American jungles found that within a region the species richness increased with increasing area but upto a certain limit. The relationship between species richness and area turned out to be rectangular hyperbola for a wide variety of taxa whether they are birds, bats, fresh water fishes or flowering plants. On a logarithmic scale it is a straight line.

$$\log S = \log C + Z \log A$$

Here S is species richness, Z is slope of line or regression coefficient, C is Y intercept while A is area.

Regression coefficient Z has generally a value of 0.1–0.2 regardless of taxonomic group or region, e.g., plants in Britain, birds in California or molluscs in New York. However, when the species-area relationship is considered for a very large area like a whole continent, regression coefficient Z or slope of the line comes to have a value of 0.6–1.2, e.g., frugivorous birds and mammals of tropical forests of different continents with a steeper line of 1.15.

Importance of Species Diversity to Ecosystems

It is very difficult to make people understand how every organism, big or small, is important for the ecosystem. What does it matter, if a species of Tree Frog becomes extinct from Western Ghats or instead of 20,000 species of ants, only 15,000 survive on earth? However, rich diversity is essential not only for ecosystems but also for the very survival of human race. Species diversity provides stability to the ecosystems. It is important for maintaining higher levels of productivity and ecosystem health.

1. **Stability.** Biodiversity is essential for stability of an ecosystem. Communities with more species tend to be more stable than those with less species. It is able to resist occasional disturbance. Alien species are unable to find a foot-hold. Destruction of a part of ecosystem does not degrade it but the ecosystem is resilient and is able to restore itself after some time. This has been confirmed by David Tilman's long term ecosystem experiments using outdoor plots.

2. **Productivity.** Ecosystems with higher biodiversity (e.g., tropical forests) are more productive than ecosystems with lower biodiversity (e.g., temperate forests). Experiments of David Tilman have confirmed that increased diversity contributes to higher productivity.

3. **Ecosystem Health.** Biodiversity is essential for maintenance and health of ecosystem.

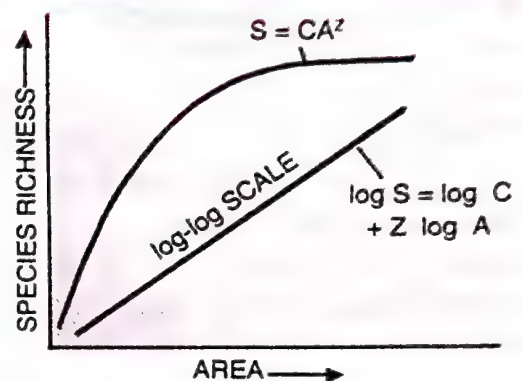


Fig. 15.6. Species-Area relationship which becomes linear on a log-log scale.

tems through the occurrence of various checks, controls, negative and positive feed backs, critical link and keystone species. No species occurs in isolation. Rather all the species are interlinked through various types of relationships. Killing or disappearance of even a few species may have a destabilising effect. Paul Ehrlich has proposed a **rivet popper hypothesis** for the effect of decrease in biodiversity on the ecosystem. An aeroplane, like an ecosystem, has thousands of rivets (=species). Removal of rivets (species) by passengers may not affect flight safety in the beginning but the plane will become dangerously weak over a period of time. Removal of rivets of a critical part like wing (or species performing major ecosystem functions) will pose a very serious immediate threat to safety.

Causes of Biodiversity Losses

The world is facing accelerated rates of species extinctions, largely due to human interference. There are four major causes— **the evil quartet**; (i) Habitat loss and fragmentation, (ii) Over exploitation, (iii) Alien species invasions and (iv) Coextinctions. However, other factors are also intensifying extinctions like disturbance and degradation, pollution, intensive agriculture and forestry.

1. **Habitat Loss and Fragmentation.** Over-population, urbanisation and industrialisation require additional land every year. It can come through destruction or fragmentation of natural habitats through filling wetlands, ploughing grasslands, cutting down trees, burning a forest and clearing some area of vegetation. Loss of habitat results in annihilation of plants, microorganisms and forcing out of animals which in alien lands die out after some time. Fragmentation of habitats (e.g., forest land surrounded by crop-lands, orchards, plantations, urban areas) results in disruption of complex interactions amongst species, destruction of species in the cleared regions, annihilation of species restricted to deeper undisturbed parts of forests and decreased biodiversity in the habitat fragments. Animals requiring large territories (e.g., mammals, birds) are badly affected. Migrating animals would go astray and get killed.

Tropical rain forests once occupied 14% of earth. Today they occur on only 6% of land area. They and other forest areas are being destroyed fast, some 170,000 Km²/yr. The Amazon rain forest was so large that it used to be called **lungs of the planet**. It probably harboured millions of species. Today it is being cut and cleared for cultivating Soy Beans and developing grasslands for raising beef cattle. Similarly, almost all natural grasslands of U.S.A. have been lost to agriculture and human settlements. 90% of wetlands of New Zealand have been destroyed by European settlers.

2. **Over-exploitation.** Excessive exploitation of a species, whether a plant or animal reduces size of its population so that it becomes vulnerable to extinction. Dodo, Passenger Pigeon, three subspecies of Tiger and Steller's Sea Cow have become extinct in the last 500 years due to over exploitation by humans. Many marine fish populations are declining around the world because of overharvesting. Some commercially important species are likely to become endangered.

3. **Alien Species Invasions.** Non-native or alien species are often introduced inadvertently for their economic and other uses. They often become invasive and drive away the local species. These species are considered to be second major cause of extinction of species (the first being habitat destruction). Exotic species have proved harmful to both aquatic and terrestrial ecosystems. Island ecosystems are the most vulnerable due to small size and small number of species. (i) Water Hyacinth (*Eichhornia crassipes*) was introduced in Indian waters to reduce pollution. It has clogged water bodies including wetlands at many places resulting in death of several aquatic plants and animals. (ii) Nile Perch (a predator fish) was

introduced in lake Victoria of South Africa. It killed and eliminated ecologically unique assemblage of over 200 native species of small Cichlid Fish. (iii) *Lantana camara* has replaced many species in forests of U.P. and M.P. *Eupatorium odoratum* has reduced the population of *Tectona grandis* in North-East. (v) *Parthenium hysterophorus* has pushed out several herbs and shrubs from open places in the plains. (vi) In 1859, an Australian farmer imported 1 dozen pair of European rabbits for game. In six years the population was 22 million. In 1930, it was 750 million causing destruction of all types of vegetation. (vii) African Catfish, *Clarias gariepinus*, has been illegally introduced for aquaculture in India. It is threatening native Catfishes (e.g., *Clarias bacterachus*) of Indian rivers. (viii) *Periplaneta americana* has replaced *Blatta orientalis* at many places.

4. **Coextinctions.** Certain obligatory mutualistic relationships exist in nature, e.g., *Pronuba yuccaselles* and *Yucca*. Extinction of one will automatically cause extinction of the other. If the host fish becomes extinct, all the parasites exclusively found on it will also become extinct.

5. **Disturbance and Degradation.** They are of two types, natural and man made. Natural disturbance and degradation are caused by spontaneous jungle fire, tree fall, pest infestation, defoliation by insects or locust attack. Man made disturbances and degradation are more severe. They include felling of trees, use of fire for clearing, collection of litter and over exploitation for other economically important products. These disturbances and degradation result in loss of biodiversity.

6. **Pollution.** Excessive use of pesticides has polluted both ground water and surface water bodies. Many sensitive species have disappeared. There is tendency of pesticide biomagnification which results in higher concentration with the rise in trophic level. It has resulted in drastic decline in the population of fish eating birds and falcons. Run off from fertiliser rich fields causes nutrient enrichment of water bodies. The phenomenon is called **eutrophication**. Sewage and other organic remains also result in eutrophication. There is an additional dense growth of plants and animals followed by depletion of oxygen, death of animals and fouling of water. Lead and other types of heavy metals poured into water bodies lead to mortality of many animals. Ducks, Swans and Cranes die of lead poisoning when they take in spent shot gun pellets falling into lakes and marshes. Lead poisoning from industries has killed many cattle drinking that water. Similarly, air pollutants cause death of sensitive plants. Radiations are also harmful to both plants and animals. Spill-over of oil in sea causes death of several marine algae, fish and sea birds. Pollution, therefore, reduces species biodiversity.

7. **Intensive Agriculture.** Spread of agriculture is at the cost of wetlands, grasslands and forests. Destruction of habitats results in extinction of species. Intensive agriculture is also based on a few high yielding varieties. As a result there is reduction in the genetic diversity. It increases vulnerability of the crop plants to sudden attack by pathogens and pests. For example, at one time about 308 varieties of Maize were growing in USA. Today their number is only 12. In Philippines, the number of Rice varieties grown prior to 1970 was 3500. Their number has fallen to merely 5.

8. **Forestry.** There is a tendency to grow economically important trees in pure strands, e.g., Sal, Teak. It drives away or annihilates other species found in forests. The pure strands are liable to be attacked by insects and pathogens.

Loss of Biodiversity

It is caused by extinction of species. Extinction is the total elimination or dying out of species from the earth.

Susceptibility to Extinction. A species becomes prone to extinction due to two categories of attributes, drastic environmental changes and population characteristics. Population traits which make a species susceptible to extinction are (i) Large body size e.g., Elephant, Rhinoceros, Bengal Tiger, Lion. (ii) Small population size. (iii) Low reproductive potential, e.g., Blue Whale, Giant Panda. (iv) Higher status of trophic level, e.g., Bald Eagle, Bengal Tiger. (v) Fixed migratory route and habitat, e.g., Blue Whale, Whooping Crane. (vi) Narrow range distribution or small geographical range, e.g., Woodland Caribou. (vii) Island species. (viii) Lack of genetic variability. (ix) Inability to switch over to alternate foods.

Types of Extinction. Extinction is of three types—natural extinction, mass extinction and anthropogenic extinction.

(i) **Natural Extinction.** Natural or **background extinction** is a slow process of replacement of existing species with the better adapted species due to alternate evolution, changes in environmental conditions, predators and diseases. A small population is more likely to become extinct sooner than the large population due to inbreeding depression (reduces genetic variability) and normal population fluctuations during unfavourable periods like drought, harsh winter or severe summer. **Extinction vertex** is a combination of genetic and demographic factors.

(ii) **Mass Extinction.** Earth has experienced five mass extinctions due to environmental catastrophes. A mass extinction occurred about 225 million years ago in Permian when 90% of shallow water marine invertebrates disappeared. Another mass extinction occurred between cretaceous and tertiary over 60 million years ago when Dinosaurs and a number of other organisms disappeared. It is also called **K-T boundary**. During pleistocene Woolly Mammoth, Mastodon, Giant Sloth and many other mammal species became extinct. Pleistocene extinctions are believed to be due to advance and retreat of ice sheets coupled with over-exploitation by hunters. K-T boundary extinctions are connected with deposits of iridium which is otherwise rare on earth.

(iii) **Anthropogenic Extinctions.** They are extinctions abetted by human activities like settlements, hunting, overexploitation and habitat destruction. Colonisation of tropical Pacific islands by humans have resulted in extinction of more than 2000 species of native birds. During the last 500 years, the earth has lost some 784 species (IUCN, 2004). It includes 338 vertebrates, 359 invertebrates and 87 plants. Some examples of important recent extinctions are Dodo (*Raphus cucullatus*) of Mauritius, Thylacine or Tasmania Wolf (*Thylacinus cynocephalus*) of Australia, Quagga of Africa or South African Zebra (*Equus quagga*), Steller's Sea Cow of Russia and three subspecies of Tiger (Bali, Javan and Caspian). In the last two decades, 27 species have become extinct. Amphibians seem to be at higher risk of extinction. Presently some 15,500 species worldwide are threatened. They include 12% bird species, 23% mammal species, 32% amphibians and 31% gymnosperms. The current rate of extinction is 100–1000 times faster than pre-human times. It seems that the earth is heading for the **sixth extinction** but it would be anthropogenic. It is believed that (a) Tropical forests are losing 2–5 species per hour or 14000–40,000 species per year. (b) Ten high endemic plant species and 3,50,000 endemic animal species in the near future. (c) If the current rate of species extinctions goes on unabated, 50% of species are liable to die out by the end of 21st century.

Loss of biodiversity is bound to cause (i) Decline in ecosystem productivity, (ii) Reduced resistance to environmental perturbations like drought, (iii) Drastic changes in ecosystem processes like water use, pest and disease cycles.

Red Data Book and IUCN

IUCN is International Union of Conservation of Nature and Natural Resources which is now called World Conservation Union (WCU). It has its headquarters at Morges, Switzerland. It maintains a red data book or red list which is a catalogue of taxa facing risk of extinction. Threatened species is the one which is liable to become extinct if not allowed to realise its full biotic potential by providing protection from exotic species/human exploitation/ habitat deterioration/depletion of food. Red data book or red list was initiated in 1963. The 2000 Red List has made assessment of 18,000 species out of which 11096 species (5485 animals and 5611 plants) are on the threatened list world-wide. The number of threatened species went up to 15,500 in 2004 (IUCN, 2004) and 17291 in 2011 (IUCN 2011). The purpose of preparation of red list is to (i) provide awareness to the degree of threat to biodiversity, (ii) provide global index about already decline of biodiversity, (iii) identification and documentation of species at high risk of extinction, (iv) preparing conservation priorities and help in conservation action, and (v) information about international agreements like Conservation on Biological Diversity and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Red list has eight categories of species.

1. **Extinct.** The taxon has been completely eliminated or died out from earth, e.g., Dodo.

2. **Extinct in Wild.** The taxon is absent in any of its natural or expected habitats in the wild. A number of domesticated animals and plants have become extinct in the wild.

3. **Critically Endangered.** The taxon is facing very high risk of extinction in the wild and can become extinct any moment in the immediate future. Their number world-wide is 925 animals and 1014 plants (10% mammals, 9% birds, 15% reptiles, 16% amphibians and 16% angiosperms). The number of critically endangered animals and plants in India is 18 and 44 respectively, e.g., *Sus salvanius* (Pigmy Hog), *Berberis nilghiriensis*, *Podophyllum*.

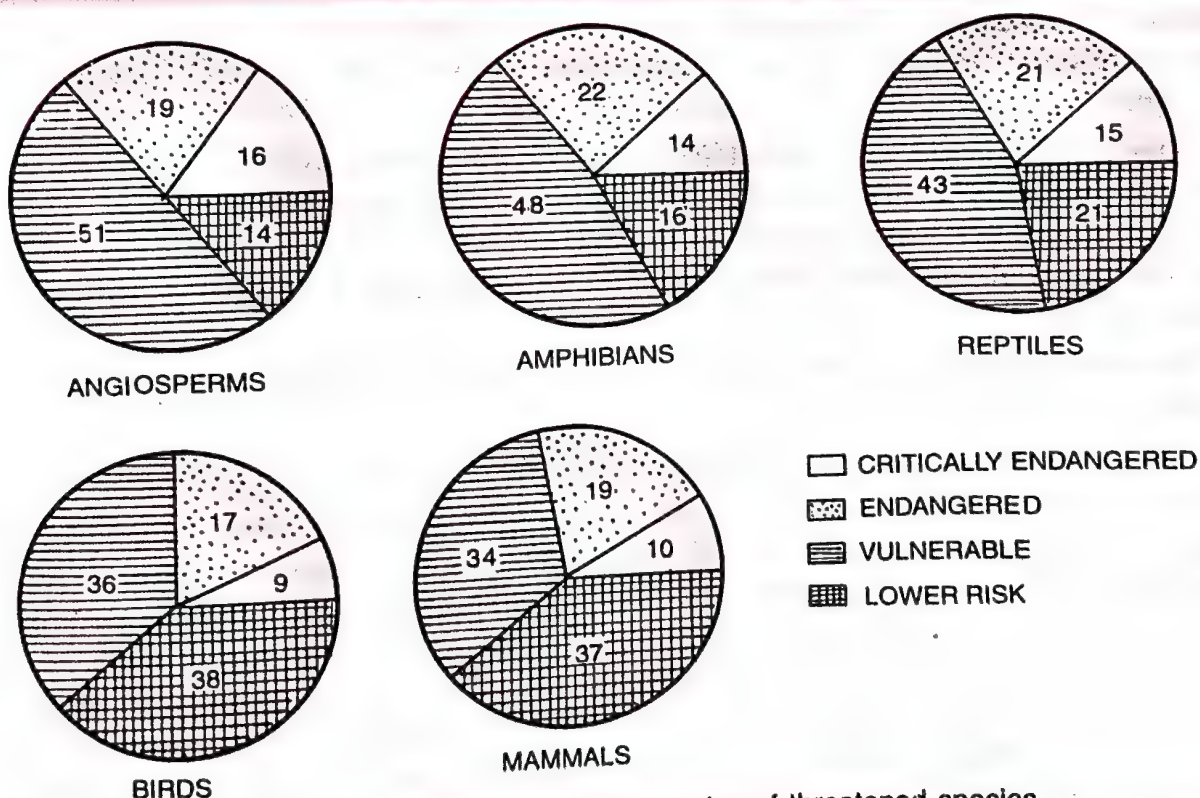


Fig. 15.7. Percentage of various categories of threatened species.

4. **Endangered.** It is facing a high risk of extinction in the wild in the near future due to decrease in its habitat, excessive predation or poaching. The percentage number of endangered species in the list of threatened ones is 19% mammals, 17% birds, 21% reptiles, 22% of amphibians and 19% angiosperms. In India, their number is 54 animals and 113 plants, e.g., *Ailurus fulgens* (Red Panda), *Bentinckia nicobarica*. Some other examples are Blue Whale, Largest Lemur *Idri idri* of Madagascar, Asiatic Wild Ass (*Asinus hemionus khur* now restricted to Rann of Kutch) and Lion Tailed Macaque (in *Dipterocarpus* forests of South India with total number of only 195).

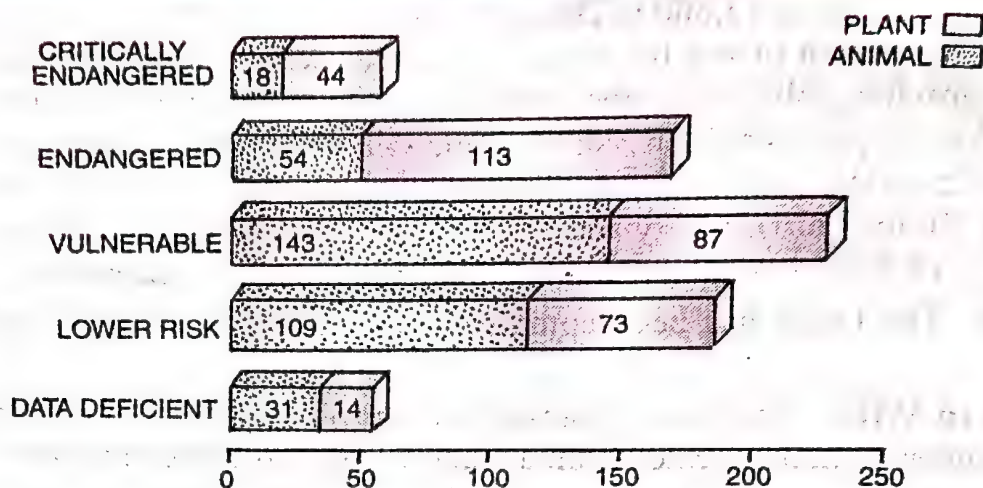


Fig. 15.8. Number of various categories of threatened species in India.

5. **Vulnerable (Depleted Species).** Presently the population is sufficient but is undergoing depletion due to some factor or factors so that it is facing risk of extinction in medium term future. Out of the total threatened species, 34–51% are vulnerable (34% mammals, 36% birds, 43% reptiles, 48% amphibians and 51% angiosperms). In India, their number is 143 animals and 87 plants, e.g., *Antelope cervicapra* (Black Buck, Indian Gazelle), *Cupressus cashmeriana*.

6. **Lower Risk.** They are threatened species which have lower risk of extinction and, therefore, require only a small attention to become normal flourishing species. The percentage of lower risk species out of the total threatened ones is 37% mammals, 38% birds, 21% reptiles, 16% amphibians and 14% angiosperms. In India their number is 109 animals and 73 plants species.

7. **Data Deficiency.** The data for making direct or indirect assessment of risk of extinction is deficient.

8. **Not Evaluated.** The taxon has not been evaluated for risk of extinction.

Out of these four categories of species are included under threatened species—critically endangered, endangered, vulnerable and lower risk species. Two more categories are also added to them. They are (i) **Rare Species (R).** They are species with naturally small populations, either localised or thinly scattered, which are always at risk from pests/pathogens/predators/exotic species. Clouded Leopard (*Neofelis nebulosa*) of Himalayas is a rare species because of poaching and loss of habitat. Hawaiian Monk Seal (*Monochus schauinslandii*) of birds found only in six small islands. Great Indian Bustard (*Ardeotis nigriceps*) is a rare species poaching. (ii) **Indeterminate Species.** The species are in danger of extinction but the

reason is not known, e.g., 3-banded Armadillo of Brazil, Short Eared Rabbit of Sumatra, Mexican Prairie Dog. As information is gathered about the status, the species is placed in terminate in 1968 and endangered in 1970.

Why Should We Conserve Biodiversity ?

There are a number of reasons why should we conserve biodiversity. They can be grouped under three categories— narrow utilitarian, broadly utilitarian and ethical.

1. **Narrow Utilitarian.** Humans derive a major part of their requirement from organisms. Their direct benefits are countless. (i) **Food.** All the food we eat comes from plants and animals — cereals pulses, fruits, vegetables, milk, eggs, meat. (ii) **Fats and Oils.** They are obtained from plants and animals. (iii) **Firewood.** Nearly two billion persons worldwide use firewood as a source of energy for cooking and heating. (iv) **Fibres.** A number of plants is used as timber in construction work, furniture, sports goods, musical instruments, etc. (v) **Timber.** Wood is used as timber in construction work, furniture, sports goods, musical instruments, etc. (vi) **Industrial Products.** Tannins, lubricants, dyes, resins, perfumes, paper, rubber, lac etc. are some of the industrial products from organisms. (vii) **Drugs.** Nearly 25% of drugs being used by us are directly coming from plants. About 25,000 plants are used by native people in traditional medicines. Many more plants of medicinal value are waiting to be explored, especially in tropical rain forests. **Bioprospecting** or exploring molecular, genetic and species level products of economic importance is going on vigorously. Nations having rich biodiversity are naturally expecting to reap enormous benefits.

2. **Broadly Utilitarian.** Biodiversity is fundamental to ecosystem services of nature. (i) **Oxygen.** Through their photosynthetic activity plants are replenishing oxygen of the atmosphere. Amazon rain forest is estimated to contribute 20% of it. Just enquire from your neighbourhood hospital about the cost of one cylinder of oxygen and calculate the value of oxygen being liberated by plants. (ii) **Pollination.** Bees, bumble bees, butterflies, moths, beetles, birds and bats are engaged in pollination of plants which is essential for formation of fruits and seeds. If humans were to do the same, the cost would be 117 billion dollars. (iii) **Climate Regulation.** Forests and oceanic systems regulate global climate. (iv) **Aquifers.** Plant cover is essential for retention of rain water, its percolation and storage in aquifers and reservoirs. (v) **Flood and Erosion Control.** Plant cover protects the soil from wind and water erosion. Run off of rain water is reduced so that flood water is rarely formed. (vi) **Nutrient Cycling.** It is essential for continued availability of nutrients to plants without which there would be no photosynthetic activity. (vii) **Microbial Waste Treatment.** It not only disposes off wastes but also generates resources. (viii) **Biological Pest Control.** In nature pests are kept under control by their natural predators. The technique is being adapted in agriculture and horticulture. (ix) **Aesthetic Value.** Biodiversity has a lot of aesthetic and attraction value. **Ecotourism** is based on it. It provides a lot of pleasure and excitement to listen to bird songs, observe blooming of flowers, bird watching and wildlife watching. The value of global ecosystem services has been calculated at 32 trillion dollars per year which is nearly double the global national product of 18 trillion dollars.

3. **Ethical.** Human beings share the biosphere with over a million species of plants, animals and microbes. They have evolved just as we have evolved. Every living species has an intrinsic value though it may not have any direct economic value. It is therefore, our moral and ethical duty not to destroy them. Instead we should take care of their well being so as to pass the rich biological legacy to future generations.

Conservation of Biodiversity

Biodiversity is important at every hierarchical level—genetic diversity (= gene pool), species diversity, community and ecosystem diversity. It is being threatened by reduction in space, smaller and fragmented habitats, over-exploitation by humans, human sponsored ecosystems, climatic change, pollution and invasive exotic species. However, it is important that the present human population derives economic, ecological and aesthetic benefits from biodiversity. It is equally important that biodiversity is preserved in all its forms and in good health for the future generations. Therefore, no decision should be made that may reduce the degree and amount of biodiversity. Further degradation and destruction of habitats should be prevented.

Conservation of biodiversity is protection, uplift and scientific management of biodiversity so as to maintain it at its optimum level and derive sustainable benefits for the present as well as future generations.

Strategies. (i) All the threatened species be protected. Priority be given to ones belonging to monotypic genera, endangered over vulnerable, vulnerable over rare and rare over other species. (ii) All the possible varieties, old or new, of food forage and timber plants, livestock, aquaculture animals and microbes be conserved. (iii) Wild relatives of all the economically important organisms be identified and conserved in protected areas. (iv) Critical habitats for feeding/breeding/resting/nursing of each species be identified and safeguarded. (v) Resting/feeding places of migratory/wide ranging animals be protected, pollution controlled and exploitation regulated. Bilateral and multilateral agreements be made where required. (vi) Life supporting system of water and soil should be conserved on priority basis. (vii) National wildlife protection laws be enacted (**In India, 1972**), wildlife protection strategies formulated (**In India 1983**) and protection programmes integrated with international programmes. **Wildlife Institute of India** is located at Dehradun (Uttarakhand). **Indian Institute of Forest Management** is situated at Bhopal. Another is **Salim Ali Centre for Ornithology and Natural History** at Coimbatore. **IBWL** is Indian Board of Wildlife (established 1952). (viii) Unique ecosystems be preserved on priority basis. (ix) The reproductive capacity of the exploited species and productivity of the ecosystem be determined. Exploitation should not exceed the same. (x) International trade in wildlife be highly regulated. India is a signatory to the convention on International trade in Endangered Species (CITES) of wild flora and fauna. (xi) Development of reserves or protected areas. (xii) Controlling introduction of alien species. (xiii) Reducing pollution. (xiv) Public awareness. (xv) There are two types of conservation strategies—*in situ* (on site) and *ex situ* (offsite).

In Situ Conservation

It is conservation and protection of the whole ecosystem and its biodiversity at all levels in order to protect the threatened species. We save the entire forest to save tiger. However, it is not economically feasible to conserve all biological wealth and all the existing ecosystems. The number of species required to be saved from extinction far exceeds the conservation resources. Two alternate methods are being used to save biodiversity, hot spots and protected areas.

1. **Hot Spots.** They are areas of **high endemism** and high level of **species richness**. Some 34 hotspots have been identified. Three of them occur in India—Western Ghats and Sri Lanka, Indo-Burma (North-East India) and Himalaya. Hotspots cover less than 2% of the total area but contain 44% of species. If they are properly conserved, they will reduce extinction by about 30%.

2. Protected Areas. They are ecological/biogeographical areas where biological diversity along with natural and cultural resources is protected, maintained and managed through legal or other effective measures. They are delimited on the basis of biological diversity, e.g., cold desert (Ladakh and Spiti), hot desert (Thar), wetland (Assam and N.E. States), saline swampy areas (Sunderbans, Rann of Kutch), mangroves, temperate forests, subtropical forests, tropical wet evergreen forests, tropical moist deciduous forests, tropical dry deciduous forests, tropical thorn, coral reefs, etc. Protected areas include national parks, sanctuaries and biosphere reserves. World Conservation Monitoring Centre has recognised 37,000 protected areas world-wide. India has about 651 protected areas of national parks (100) and wildlife sanctuaries (551), 18 biosphere reserves and many sacred groves covering 4.7% land surface against 10% internationally.

Benefits. (i) Maintaining genetic diversity of all the present species and varieties. (ii) Maintaining viable populations of native species, subspecies and varieties. (iii) Maintaining resilience in species/habitats/ecosystems to adapt to environmental changes. (iv) Maintaining the various types of communities/ecosystems/habitats both in number and distribution. (v) Checking human aided introduction of alien exotic species.

National Parks. They are areas maintained by government and reserved for betterment of wildlife. Cultivation, grazing, forestry and habitat manipulation are not allowed. There are 100 national parks (66 in 1988) in India occupying nearly 1.1% of geographical area. A few of them have been declared as world heritage sites — Kaziranga, Keoladeo and Manas. The first national park of India was Jim Corbett National Park (1936). Some early national parks of world are Yellowstone Park (USA) and Royal Park (near Sydney, Australia).

Sanctuaries. They are tracts of land with or without lake where wild animals/fauna can take refuge without being hunted. Other activities like collection of forest products, harvesting of timber, private ownership of land, tilling of land, etc. are allowed. India has 551 (368 in 1988) sanctuaries occupying over 3.6% of geographical area.

Differences between National Park and Sanctuary

<i>National Park</i>	<i>Sanctuary</i>
1. It is meant for protection of both flora and fauna.	1. It is meant for protection of only fauna.
2. Cultivation of land is not permitted.	2. Cultivation of land is permitted.
3. Grazing is not allowed.	3. Grazing is allowed.
4. Forest products are not harvested.	4. Forest products are harvested.
5. Private ownership is not permitted.	5. Private ownership is permitted.
6. Boundary is well demarcated.	6. Boundary is not well demarcated.

Biosphere Reserves. They are multipurpose protected areas which are meant for preserving genetic diversity in representative ecosystems of various natural biomes and unique biological communities by protecting wild populations, traditional life style of tribals and domesticated plant/animal genetic resources. Creation of biosphere reserve was initiated in 1975 under MAB programme of UNESCO. Till May 2002, 408 biosphere reserves had been established in 94 countries. In India, 18 biosphere reserves have been set up by now (Fig. 15.9.). Four of them are recognised as world heritage sites — Nanda Devi, Sunderbans, Nilgiri and Gulf of Manar. They are also notified as national parks. Each biosphere reserve

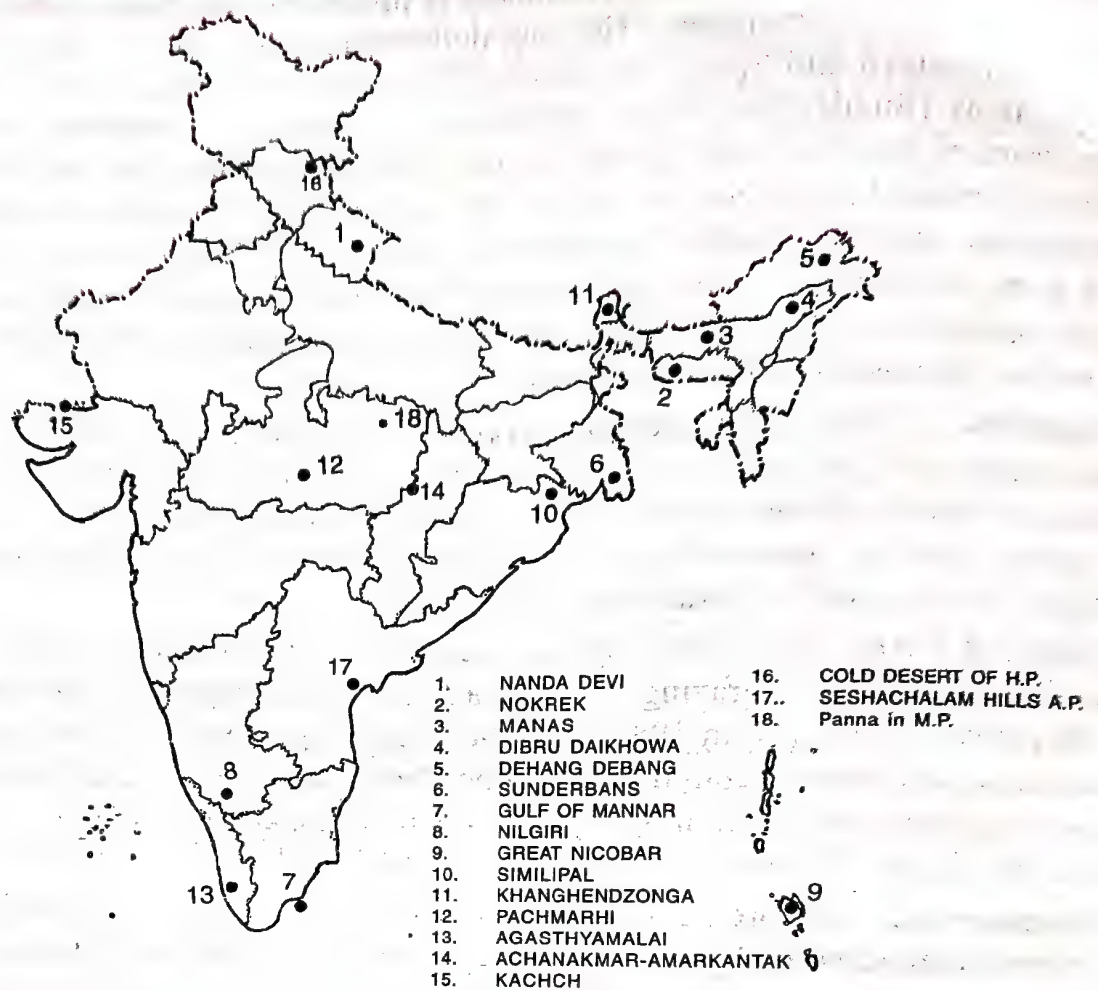


Fig. 15.9. Biosphere reserves of India.

(Fig. 15.10.) has (i) **Core or Natural Zone**. No human activity is allowed. The area is undisturbed and legally protected ecosystem. (ii) **Buffer Zone**. It surrounds the core area. Limited human activity is allowed like resource use strategies, research and education. (iii) **Transition Zone** (Manipulation Zone). It is the outermost or peripheral part of biosphere reserve where an active cooperation is present between reserve management and local people for activities like settlements, cropping, recreation, forestry and other economic uses without disturbing ecology. Transition zone has different parts like forestry, agriculture, tourism and restoration regions. **Restoration region** is degraded area which is selected for restoration to near natural form.

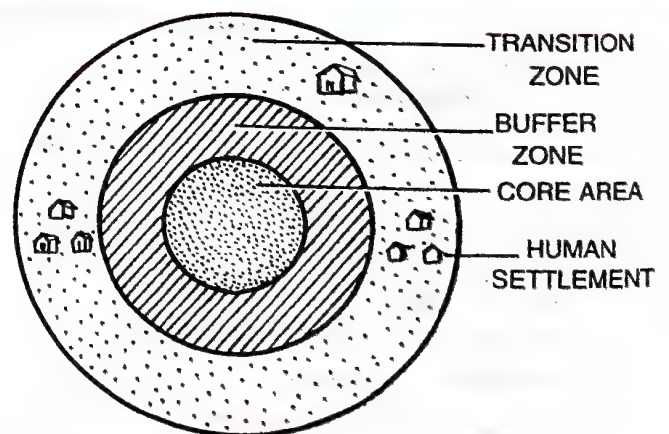


Fig. 15.10. Zonation in terrestrial biosphere.

Importance. (i) **Restoration.** Biosphere reserves help in restoration of degraded ecosystems and habitats. (ii) **Conservation.** They are a means of conserving genetic resources, species, ecosystems and landscapes without uprooting the local people. Rather their traditional life style and traditional resources are maintained. (iii) **Development.** They

ensure culturally, socially and ecologically sustainable economic development. (iv) **Monitoring.** There is a regular monitoring of development and conservation progress. (v) **Education and Research.** Each biosphere reserve supports education and research in various ecological aspects of the ecosystem/biome. There is also exchange of information about research, restoration, conservation and development aspects at the national and global levels.

MAB Programme. Man and biosphere programme is an international biological programme of UNESCO (United Nations Educational Scientific and Cultural Organisation) which was started in 1971 but was introduced in India in 1986. MAB has studied human environment, impact of human interference and pollution on biotic and abiotic environments and conservation strategies for the present as well as future.

Ramsar Sites

Wetlands are called Ramsar sites because the first international convention on their conservation was held in Ramsar in Iran in 1971. Wetlands or Ramsar sites are low lying marshy areas which get filled up during rains due to runoff and overflow from other water bodies. They are often considered to be waste lands which are used as dumping areas and filled up to recover land for various construction activities. As a result, a large number of wetlands have disappeared.

Wetlands are ecologically quite important : (i) They are an important source of recharging ground water. (ii) Wetlands provide protection from floods by picking up water from runoff and spills from other sources. (iii) They are good source of siltation and purification of water. (iv) A number of aquatic biota are resident of wetlands. (v) Trees and shrubs growing on the margins of wetlands provide residence to many native and migratory birds. Migratory bird Flamingo (Hansawar) breeds in Rann of Kutch. It is therefore, important to conserve wetlands by checking dumping of waste materials, bordering wetlands with shrubs and trees. Some 16 wetlands have been selected in India for priority conservation, e.g., Harike (Punjab), Chandra Tal (H.P.), Bhojeutland (MP), Biharkanika Manaroves (Odisha), Ashtmudi (Kerala). Wetland day is February 2.

Fresh water wetlands occur over land. Salt water wetlands occur as estuaries and mangrove swamps over coastal areas.

Sacred Forests and Lakes. Sacred forests (= sacred groves) are forest patches around places of worship which are held in high esteem by tribal communities. They are the most undisturbed forest patches (island of pristine forests) which are often surrounded by highly degraded landscapes. They are found in several parts of India, e.g., Karnataka, Maharashtra, Rajasthan (Aravalli), Chhatisgarh (Sarguja, Chanda and Bastar), Kerala, Meghalaya. Temples built by tribals are found surrounded by Deodar forests in Kumaon region. In Meghalaya, sacred graves are found in Jaintia and Khasi hills. Not a single branch is allowed to be cut from these forests. As a result many endemic species which are rare or have become extinct elsewhere can be seen to flourish here. Bishnois of Rajasthan protect *Prosopis cineraria* and Black Buck religiously. Rajasthan has several hundred sacred groves and sacred landscapes (Orans). Some water bodies are also held sacred in certain places, e.g., Khecheopalri in Sikkim. Their aquatic flora and fauna are naturally preserved.

Ex Situ Conservation

It is conservation of selected rare plants/animals in places outside their natural homes. *Ex situ* conservation includes offsite collections and gene banks. The two are also a source of genetic material for breeders and genetic engineers.

1. **Offsite Collections.** They are live collections of wild and domesticated species in botanical gardens, zoological parks, wildlife safari parks, arboreta (= arboretums= arbouretums), etc. Currently, there are more than 1500 botanical gardens and arboreta (gardens with trees

and shrubs) having more than 80,000 species. Many of them have seed banks, tissue culture facilities and other *ex-situ* technologies. The number of zoos/zoological parks is more than 800. They have about 3000 species of mammals, birds, reptiles and amphibians. Most of them have well managed captive breeding programmes. As a result many animals which have become extinct in the wild continue to be maintained in zoological parks. Captive breeding is also resorted to in those cases where the number of surviving individuals is so small that there is no realistic chance of *in situ* survival. As the number increases in captive breeding, the individuals are selectively released in the wild. By this method Californian Condor (*Gymnogyps californicus*) and Black-Footed Ferret (*Mustela nigripes*) have been saved from extinction. Ginkgo Tree (*Ginkgo biloba*) has been saved by selective breeding followed by channelling into trade of nature lovers. Therefore, offsite collections can be used to restock depleted populations, reintroduce species in the wild and restore degraded habitats.

2. Gene Banks. They are institutes that maintain stocks of viable seeds (seed banks), live growing plants (orchards), tissue culture and frozen germplasm with the whole range of genetic variability.

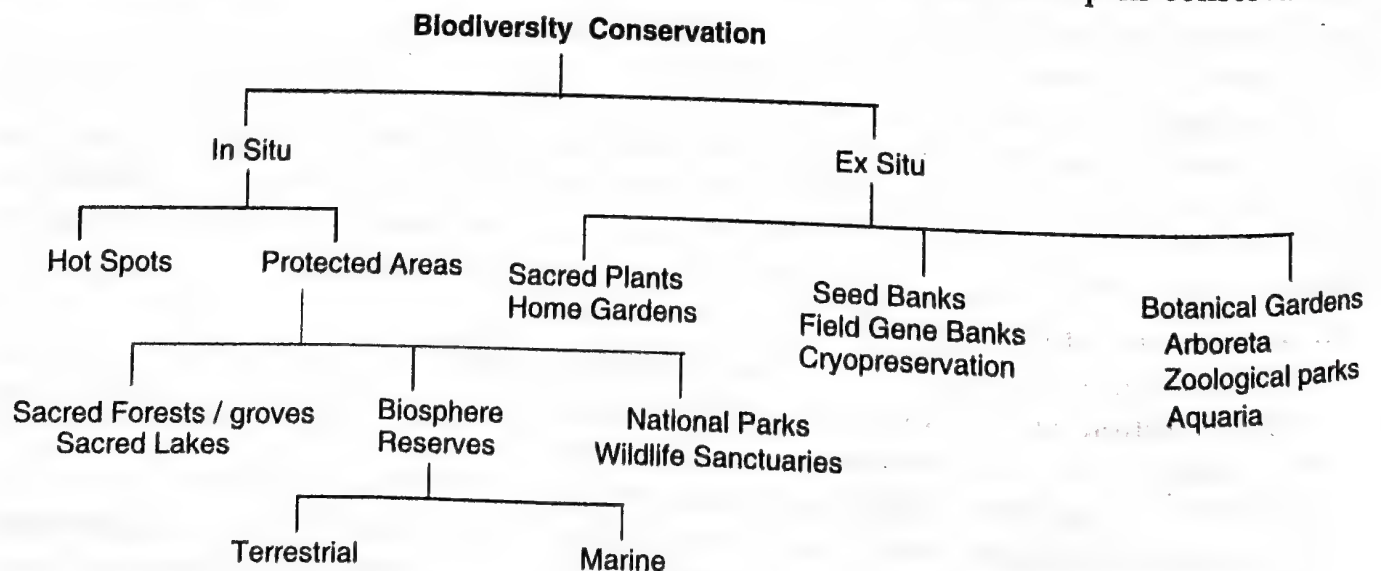
(i) **Seed Banks.** Seeds are of two types, orthodox and recalcitrant. **Orthodox seeds** are those seeds which can tolerate reduction in moisture content (upto 5%), anaerobic conditions and low temperature of -10° to -20°C or even lower for prolonged periods, e.g., cereals, legumes. At intervals the seeds are allowed to germinate, form plants and develop fresh seeds for storage.

Recalcitrant seeds are those seeds which get killed on reduction of moisture and exposure to low temperature, e.g., Tea, Cocoa, Jackfruit, Coconut. They can be stored for shorter duration after treatment with fungicides in rooms having humid air and normal oxygen.

(ii) **Orchards.** Plants with recalcitrant seeds are grown in orchards where all possible strains and varieties are maintained, e.g., Litchi, Oil Palm, Rubber Tree, etc.

(iii) **Tissue Culture.** It is carried out through callus formation, embryoids, pollen grain culture and shoot tip culture for those plants which are either seedless, have recalcitrant seeds, variable seed progeny or where clone is to be maintained. The method is useful in maintaining a large number of genotypes in small area, rapid multiplication of even endangered species and for hybrid rescue. Shoot tip culture maintains virus free plants. It is used for international exchange of germplasm in vegetatively multiplied cultivars, e.g., Banana, Potato.

(iv) **Cryopreservation.** Preservation at -196°C (liquid nitrogen) can maintain tissue culture, embryos, animal cells/tissues, gametes indefinitely. The cryopreserved material is revived through special technique when required. In order to prevent extinction, endangered organisms are being cryopreserved so that they can be revived to help in conservation.



Differences between *In situ* and *ex situ* Conservation

<i>In situ</i> Conservation	<i>Ex situ</i> Conservation
1. It is conservation of endangered species in their natural habitats.	1. It is conservation of endangered species outside their natural habitats.
2. The endangered species are protected from predators.	2. The endangered species are protected from all adverse factors.
3. The depleting resources are augmented.	3. They are kept under human supervision and provided all the essentials.
4. The population recovers in natural environment.	4. Offspring produced in captive breeding are released in natural habitat for acclimatisation.

Hot Spots (Norman Myers, 1988)

They are areas with high density of biodiversity or megadiversity which are also the most threatened ones. Ecologically hot spots are determined by four factors. (i) Number of species/species diversity. (ii) Degree of endemism (0.5% or 1500 species). (iii) Degree of threat to habitat due to its degradation and fragmentation (70% of primary vegetation). (iv) Degree of exploitation. Myers (1988) initially identified 12 hot spots with 14% of plant species in an area of only 0.2%. Four more hotspots were added by Myers (1991). Today the number of hotspots identified by ecologists is 34 covering an area less than 2% of land surface with about 20% of human population living there. There are 15 hotspots in tropical forests, 5 in mediterranean type forests and 9 in islands. The total number of hotspots in tropics is 16, 15 mainland and one island. India has three hotspots— Indo-Burma, Himalayas, Western Ghats-Sri Lanka. India is even otherwise a country of megadiversity with 2.4% of land area and having 8.1% of global diversity. There are seventeen such countries covering 10% of land surface with 70% of total biodiversity.

(i) **Western Ghats** occur along the western coast of India for a distance of about 1600 km in Maharashtra, Karnataka, Tamil Nadu and Kerala extending over to Srilanka. At low elevation upto 500 m above sea level, the area contains tropical evergreen rain forests while semi-evergreen forests occur at a height of 500–1500 m. Major centres of biodiversity are Agasthyamalai hills, Silent valley and Amambalam Reserve. There is high degree of endemism as well as richness of species of flowering plants, amphibians, reptiles, some mammals and butterflies. (ii) **Indo-Burma** hot spot extends from Bhutan to Myanmar covering most of north-east. Valleys of this region are rich in endemic species. It has been an active centre of evolution of flowering plants, being rich in primitive angiosperm genera (*e.g.*, *Magnolia*, *Betula*) and primitive angiosperm families (*e.g.*, Magnoliaceae, Winteraceae). The region has tropical forests below the elevation of 1500 m and temperate forests between 1780–3500 m. A number of crop plants originated in this hot spot. (iii) **Himalayan** hot spot is spread all along northern and north western high mountainous ranges having snow covered peaks. Because of the latter there is high degree of endemism. The number of endomic dicot species is alone 3169.

International Efforts For Conserving Biodiversity

Earth Summit at Rio de Janeiro (1992), Brazil, promoted Convention on Biological Diversity (CBD) which was signed by 152 nations. Its recommendations came into effect on 29th Dec. 1993. India became a party to this Convention on Biological Diversity in May, 1994. The various commitments were (i) Adoption of ways and means to conserve biodiversity. (ii) Managing biodiversity for sustainable use. (iii) Ensuring equitable sharing of benefits from biological diversity including utilisation of genetic resources. **Agenda 21**, a product of Earth

Summit, is a blue print for encouraging sustainable development of diversity through social, economic and environmental measures in the 21st century.

A second World Summit was held in 2002 in Johannesburg, South Africa. 190 countries attending the Summit pledged to significantly reduce the current rate of biodiversity loss at global, regional and local levels by 2010. An **Earth Summit (Rio + 20)** was again held in 2012 in Rio de Janeiro to chalk out new strategies for sustainable development.

Some nongovernmental organisations (NGO's) like **green peace** provide international support for conservation. World Conservation Union (former IUCN) is an international independent organisation which provides leadership, common approach and expertise in arena of conservation. Another similar organisation is World Wide Fund for Nature (WWF). Convention in International Trade in Endangered Species (CITES) has helped in restricting poaching and loss of rare species. Restriction on trading in animal products is believed to have saved the elephant from extinction. Establishment and maintenance of biosphere reserves are helped by UNESCO under its Man and Biosphere (MAB) programme.

Biodiversity Conservation in India

1. India is **centre of origin** and **natural home** of 167 **cultivated species**. It is home land of some 320 wild relatives of crop plants. The latter include Rice, Sugarcane, Millets (crop plants), Banana, Mango (fruit plants), Jackfruit, Cucurbits, *Dioscorea*, *Alocasia*, *Colocasia* (vegetables), Cardamom, Black Pepper, Ginger, Turmeric (spices and condiments), Brassicas (oil and vegetables).

2. India is centre of origin for some animal species like Zebu (*Bos indicus*), Water Buffalo (*Babalus arnee* = *B. bubalus*), Mithum (*Bos frontalis*, Gayal), Chicken (*Gallus domesticus*) and Camel (*Camelus dromidarius*).

3. Bamboos and tree cotton also originated in India.

4. India is **secondary home** (= secondary centre of domestication) of some animals (e.g., Sheep, Goat, Horse, Cattle, Yak, Donkey) and plants (e.g., Maize, Potato, Tobacco).

Because of the abundant diversity present in the country, its conservation is very important not only for the country but also for the rest of the world. Both *in situ* and *ex situ* conservation measures are being undertaken. *In situ* conservation is being undertaken by national parks, wildlife sanctuaries and biosphere reserves. It is being managed by Ministry of Environment and Forests. Joint Forest Management (JFM) is practised in 10.25 million hectares of previously degraded forests through 36075 village forest protection committees. It is useful to local and tribal people as they become partner in nonwood forests products.

Land races, different types of food and medicinal plants are being conserved by tribal people, women and some nongovernmental agencies. It is because of women that plants like *Ocimum sanctum* and *Aloe vera* have continued to survive. A scheme of maintaining community registers of genetic resources and resource management is being planned.

Major *ex situ* conservation of biodiversity is being managed by **National Bureau of Plant, Animal and Fish Genetic Resources**. There is an International Crop Research Institute for Semi-Arid Tropics (ICRISAT) in Hyderabad for conserving germplasm of Groundnut, Pigeon Pea, Chick Pea, Pearl Millet and Sorghum. A number of other centres in India are maintaining hundred and thousands of present and past varieties of crop plants. Thus, germplasms of plants and animals are being conserved *in vitro* in gene/seed banks, field gene banks, botanical gardens and zoological gardens. Being spread over different parts of the country, the various institutes are conserving regional variants of all types of important plants and animals.

ADDITIONAL INFORMATION

- Hornbill (a bird) is the symbol of the Bombay Natural History Society.
- Kailash Sankhala wrote the widely acclaimed book **Tiger I Tiger I**
- **The Silent Valley** is so called because it is silent during the night. It is in Kerala.
- Wild life Institute of India (WII), Dehradun.
- Haryana has named all its tourist resorts after birds.
- "Appiko" movement started in 1983 in Karnataka. 'Appiko' means the same as 'Chipko' — hug.
- Sunderlal Bahuguna started the "Chipko movement" which resisted deforestation.
- Wildlife Protection Act, 1972
- Forest conservation Act, 1980.
- **Red Data Book**. This book contains a record of Animals and Plants which are known to be in danger. This book is maintained by IUCN.
- **Keoladeo Ghana National Park, Bharatpur, Rajasthan** was once the duck-shooting ground of a king.
- In 1935 the "Hailey National Park" in Uttarakhand was renamed as Corbett National Park.
- The hunting of **Great Indian Bustard** (endangered bird) by Arab Sheikhs was stopped in India only in 1977 when wildlife lovers created an uproar.
- **The First Earth Day** was celebrated in 1970 by a group of people of America to draw attention to increasing environmental problems caused by humans on earth.
- **Zoos**. 275 in India.
- **21st March** — World Forest Day.
- **22nd March** — World water day.
- **22nd April** — World Earth Day.
- **5th June** — World Environment Day.
- **3rd October** — World Animal Day
- First week of October (monday) — Wildlife Week
- **3rd December** — World Conservation Day
- **29th December** — Biological Diversity Day
- **MAB** — Man and Biosphere Programme
- **WWF** — The World Wildlife Fund for Nature
- **IBWL** — Indian Board for Wildlife
- **IBP** — International Biological Programme
- **IUCN** — The International Union for Conservation of Nature and Natural Resources
- **UNDP** — United Nations Development Programme

NCERT TEXT BOOK QUESTIONS WITH ANSWERS

1. Name the three important components of biodiversity.
✓ Genetic diversity, species diversity and ecological diversity.
2. How do ecologists estimate the total number of species present in the world ?
✓ (i) Temperate areas are taxonomically the most thoroughly investigated regions of the world. The number of species of any exhaustively studied group is compared between temperate and other regions, say tropics. The ratio is applied to calculate the possible number of species of another group in the area which has not been thoroughly explored (ii) Rough estimate from the rate of finding of new species also gives an idea of total diversity in the area.
Based on these two criteria Robert May has estimated the number of species to be 7 million.
3. Give three hypotheses for explaining why tropics show greatest levels of species richness.
✓ (i) **Favourable Climate**. In tropics the climate is favourable for growth throughout the year. (ii) **No Glaciation**. Tropics have not faced any glaciation which has caused destruction of species in temperate and subarctic regions. (iii) **Sunlight**. Abundant sunlight is available throughout the year in tropics only.
4. What is the significance of the slope of regression in a species-area relationship ?
✓ Alexander von Humboldt observed that within a region, species richness (number of species per unit area) increases with increasing explored area, but only upto a limit. On a logarithmic scale, the relationship is a straight line ($\log S = \log C + Z \log A$). The value of Z i.e., slope of regression (regression coefficient) of species-area relationships is similar and lies in the range of 0.1 to 0.2 when analysis is done among small areas. However, if the species -area relationship is for very large areas like entire continent, the slope of the line is much steep with value of Z in the range of 0.6 to

1.2. Thus larger the explored area, more is steepness of the slope of line. Biodiversity also changes with the change in altitude. It increases from higher to lower altitudes.

5. What are the major causes of species losses in a geographical region ?
 ✓ The major causes of loss of species are (i) Habit loss and fragmentation. (ii) Over-exploitation. (iii) Invasion of alien species. (iv) Co-extinction (v) Disturbance and degradation. (vi) Pollution. (vii) Intensive agriculture. (viii) Monoculture forestry.

Refer to the text for explanations.

6. How is biodiversity important for ecosystem functioning ?
 ✓ The rich biodiversity is important for stability, productivity, resilience, alternative pathways and health of the ecosystems. David Tilman confirmed that higher the biodiversity, higher is the productivity of the ecosystems. He also confirmed that if an ecosystem is rich in species diversity, there is very little year to year variation in total biomass. Rich biodiversity provides resilience against natural/man made disturbance and invasion by alien species. The species richness is essential for ecosystem health as well to survival of the human race on this planet. The rivet popper hypothesis of Paul Ehrlich has explained the effect of reduction in biodiversity by citing an example. In an air plane (analogous to ecosystem), all parts are joined together by thousands of rivet (= species). If passengers start popping rivets and taking them have (similar to species extinction), there may be no effect in the flight safety in the beginning but as more and more rivets are removed, the aeroplane becomes dangerously weak over a period of time. Loss of key rivets on the wings (= Key species of the ecosystem driving major functions) would result in crash of aeroplane.

7. What are sacred groves ? What is their role in conservation ?

✓ Sacred groves are the traditionally protected patches of forests around places of worship where local tribal communities do not allow to cut even a simple branch of the tree because of religious sanctity according to them. Such sacred groves in India are found in western ghats of Karnataka and Maharashtra, Khasi and Jaintia hills in Meghalaya, Aravalli hills of Rajasthan and Sarguja, Chanda and Bastar areas of Madhya Pradesh. These sacred forests are serving as refugia for a number of rare, endangered and endemic species.

8. Among the ecosystem services are control of floods and soil erosion. How is this achieved by the biotic components of the ecosystem ?

✓ Ecosystem services are products or benefits given by ecosystem processes to the environment for its purification, beauty, biodiversity, protection of natural resources, habitat to wild life and tribals, protection of soils, CO_2 - O_2 balance, retention of water against floods, droughts and pollution. The biotic components of ecosystem are plants, animals, micro organisms. Plants help in controlling floods and check soil erosion. Their roots hold the soil particles against moving water and wind and thus prevent soil erosion by water and wind. They also increase the porosity of soil and thereby allow water to percolate down into the soil. They help to retain water and prevent run off of rain water. The rain water is held over the soil by plant litter like a sponge which percolates down slowly and slowly and stored as underground water. A forest tree can held up 5000 — 6000 litre of water below it this help in controlling of floods.

9. The species diversity of plants (22%) is much less than that of animals (72%). What could be the explanations to how animals achieved greater diversification ?

✓ Animals have achieved greater diversification than plants due to reasons : (i) They have nervous system to receive stimuli and respond against them. Most of their responses are adaptive for their survival in changing environment. (ii) They are mobile and to avoid competition. They show niche specialization. (iii) They are subjected to less seasonal and more constant environment. Plants are fixed and require fewer evolutionary adaptations in order to obtain their requirement of water, minerals and sunlight or avoid destruction due to excessive herbivory. All this has resulted in higher species diversity among animals than plants.

10. Can you think of a situation where we deliberately want to make a species extinct ? How would you justify it ?

✓ Yes. Extremely harmful pathogens. Many pathogens have little role in ecosystem. Their extinction will not make any effect on ecological balance, e.g., Small pox Virus. Poliovirus is about to get eradicated. Efforts are continued to make this world free from diseases like TB, AIDS, Malaria, Hepatitis, diphtheria, tetanus etc. These microorganisms have no role in biocontrol. They are neither producers nor decomposers of any ecosystem and their extinction would not affect the functioning of ecosystems in any way.

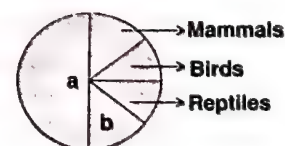
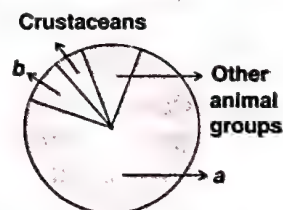
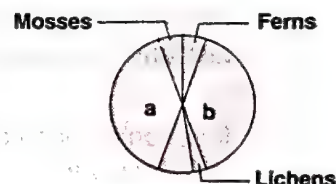
TEXT QUESTIONS

One Mark Questions (With answers)

- What is the function of National Bureau of Plant Animal and Fish Genetic Resources.
✓ To collect and conserve the germplasm of plants and animals in seed gene banks and field gene banks for *in vitro* conservation.
- India is homeland of how many cultivated plants and their wild relatives.
✓ 167 cultivated crop species and 320 wild relatives.
- Name animal species for which India is centre of biodiversity.
✓ Zebu, Mithun, Chicken, Water Buffalo, Camel.
- Name animal species for which India is secondary centre of domestication.
✓ Horse, Goat, Sheep, Cattle, Yak, Donkey.
- Name crop plants, fruit plants and vegetables for which India is centre of biodiversity.
✓ **Crop Plants.** Rice, Sugarcane, Tea, Millet. **Fruit Plants.** Mango, Banana. **Vegetables.** Cucurbits, Jackfruit, Dioscoreas, *Alocasia*, *Colocasia*.
- Name plants for which India is secondary centre of domestication.
✓ Potato, Maize, Tobacco.
- Name the region of biosphere reserve which is legally protected and where no human activity is allowed.
✓ Core zone.
- Match the words in column I with those of column II

Column I	Column II
(i) 13,000 genes	(a) <i>Lantana camara</i>
(ii) Anticancer drug	(b) <i>Magnolia</i>
(iii) Exotic species	(c) <i>Drosophila melanogaster</i>
(iv) Primitive genus	(d) Humans
	(e) Yew tree.

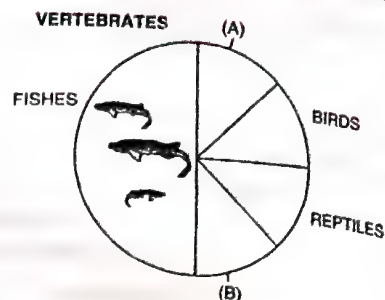
 ✓ (i) – c, (ii) – e, (iii) – a, (iv) – b.
- Name the unlabelled areas 'a' and 'b' of the pie chart representing the biodiversity of plants showing their proportionate number of species of major taxa. (CBSE 2009)
✓ a – Fungi b – Angiosperms
- Name the unlabelled areas 'a' and 'b' of the pie chart (given above) representing the global biodiversity of invertebrates showing their proportionate number of species of major taxa. (CBSE 2009)
✓ a – Insects b – Molluscs
- Name the unlabelled areas 'a' and 'b' of the pie chart representing biodiversity of vertebrates showing the proportionate number of species of major taxa. (CBSE 2009)
✓ a – Fishes b – Amphibians
- India has more than 50,000 strains of rice. Mention the level of biodiversity it represents. (CBSE 2010)
- Write the importance of cryopreservation in conservation of biodiversity. (CBSE 2011)
- Name the type of biodiversity represented by the following :
 - 50,000 different strains of rice in India
 - Estuaries and alpine meadows in India. (CBSE 2013)
- Name the type of biodiversity represented by the following :
 - 1000 varieties of mangoes in India.



(b) Variations in terms of potency and concentration of reserpine in *Rauwolfia vomitoria* growing in different regions of Himalayas.

(CBSE 2013)

16. Identify (A) and (B) in the figure given here representing number of major vertebrate taxa. (CBSE 2014)



(CBSE 2010)

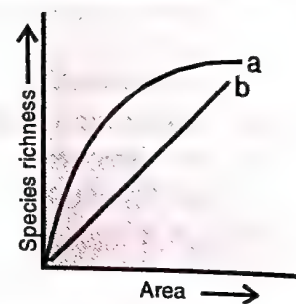
(CBSE 2010)

(CBSE 2010)

(CBSE 2010)

(CBSE 2010)

(CBSE 2011)



(CBSE 2013)

(CBSE 2013)

(CBSE 2015)

(CBSE 2016)

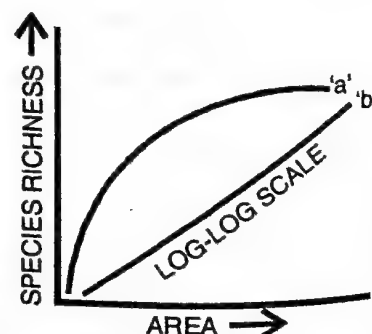
(CBSE 2016)

Two Mark Questions (With Sample Answers)

- Giving two reasons explain why there is more species of biodiversity in tropical latitudes than in temperate ones. (CBSE 2010)
- Alien species are a threat to native species. Justify taking examples of an animal and a plant alien species. (CBSE 2010)
- In the biosphere immense biological diversity exists at all levels of biological organisation. Explain any two levels of biodiversity. (CBSE 2010)
- Biodiversity must be conserved as it plays an important role in many ecosystem services that nature provides. Explain any two services of the ecosystem. (CBSE 2010)
- Why certain regions have been declared as biodiversity "hot spots" by environmentalists of the world? Name any two "hot spot" regions of India. (CBSE 2010)
- State the use of biodiversity in modern agriculture. (CBSE 2011)
- The graph shows species-area relationship. Write the equation of curve 'a' and explain. (CBSE 2011)
- Differentiate between *in situ* and *ex situ* approaches of conservation of biodiversity. (CBSE 2011)
- Justify with example where a deliberate attempt by humans has led to the extinction of a particular species. (CBSE 2011)
- Where would you expect more species biodiversity in tropics or in polar regions? Give reasons in support of your answer. (CBSE 2013)
- "Stability of a community depends upon its species richness". Write how did David Tilman show this experimentally. (CBSE 2013)
- What is meant by "alien species" invasion? Name one plant and one animal alien species that are a threat to our Indian native species. (CBSE 2013)
- List any four techniques where principle of *ex-situ* conservation of biodiversity has been employed. (CBSE 2015)
- Mention the kind of biodiversity of more than a thousand varieties of mangoes in India represent. How is it possible? (CBSE 2016)
- Why are sacred groves highly protected? (CBSE 2016)

Three Mark Questions (Short Answer Questions)

- A particular species of wild cat is endangered. In order to save it from extinction which is desirable approach, *in situ* or *ex situ*. Justify your answer and explain the difference between the two approaches. (CBSE 2009)
- Why are (i) Alien species invasion and (ii) Loss of habitat and fragmentation, considered to be the major cause of loss of biodiversity? Explain with the help of one example each. (CBSE 2009)
- Alien species are highly invasive and are a threat to indigenous species. Substantiate this statement with any three examples. (CBSE 2012)
- The graph shows species area relationship. Answer the following (a) Name the naturalist who studied two kind of relationship shown in the graph. Write the observation made by him. (b) Write the situations as discovered by ecologists when the value of 'Z' (slope of line) lies between (i) 0.1 and 0.2 (ii) 0.6 and 1.2. What does 'Z' stand for. (c) When would the slope of line 'b' become steeper? (CBSE 2014)
- There are many animals that have become extinct in the wild but continue to be maintained in zoological parks. (a) What type of biodiversity conservation is observed in this case? (b) Explain any other two-ways which help in this type of conservation. (CBSE 2014)
- Since the origin of life on earth, there are five episodes of mass extinction



of species. (a) How is the 'sixth extinction' presently in progress different from the previous episodes? (b) Who is mainly responsible for the sixth extinction? (c) List any four points that can help overcome this disaster. (CBSE 2014)

7. Explain giving three reasons, why tropics show greatest levels of species diversity. (CBSE 2014)
8. Many plant and animal species are on the verge of their extinction because of loss of forest land by indiscriminate use by humans. As a biology student what method would you suggest alongwith its advantage that can protect such threatened species from getting extinct. (CBSE 2015)
9. Compare narrowly utilitarian and broadly utilitarian approaches to conserve biodiversity with the help of suitable examples. (CBSE 2015)

Five Mark Questions

1. Write short notes on the following. (a) *Ex-situ* conservation (b) Hot spots of biodiversity (c) Biosphere reserves (d) IUCN Red List (e) Protected areas.
2. (a) What is biodiversity? Why has it become important recently?
(b) Describe the uses of biodiversity.
3. What kind of threats to biodiversity may lead to its loss? (CBSE 2009)
4. (a) Taking one example each of habitat loss and fragmentation, explain how are the two responsible for biodiversity loss.
(b) Explain two different ways of biodiversity conservation. (CBSE 2012)
5. (a) Why should we conserve biodiversity? How can we do it?
(b) Explain the importance of biodiversity hot spots and sacred groves. (CBSE 2016)

Value Based Question

1. We often read in newspapers that leopard, tiger, lion, crocodile or elephant has killed human beings and their livestock. Even then, Government of India, is creating more and more reserves for them, some 43 alone for tigers. Why?
✓ Every animal is a link in food chain and a repository of a particular genome. The food chains are built up in such a way that there is a biological control at every step. If the chain is broken, the biological control is lifted resulting in large scale disturbance and destruction of biota. President Roosevelt of U.S.A. ordered killing of carnivores of a national park so that deer could live peacefully. However, within a decade, the national park changed into a desert with no deer to play there.
2. Wetlands are breeding places of mosquitoes. Even then they are very important for maintaining ecological balance. How?
✓ Wetlands are marshy and swampy areas which get filled up during rains from runoff water, overflowing rivers, rivulets and channels. (i) By picking up extra water, wetlands prevent flooding. (ii) They help in recharging ground water. (iii) They purify runoff water because wetlands function as sedimentation traps. (iv) A number of plants, animals and microorganisms reside in wetlands. (v) They attract a number of birds, both local and migratory.
Their benefit of recharging ground water and preventing floods overweighs all other uses. Therefore, despite being breeding places of mosquitoes, maintenance of wetlands is an ecological necessity. Moreover, presence of mosquitoes and their larvae will attract their natural predators.
3. India is one of the seventeen megadiversity centres of the world. It has three of 34 hotspots of biodiversity. What do you understand by the two terms. State the values attached to them.
✓ **Megadiversity centres** are areas or countries which have a very high density of biodiversity. Their area is small as compared to biodiversity. The seventeen megadiversity centres of the world cover only 10% of the land surface but contain 70% of total biodiversity. India with 2.4% of land area supports 8.1% of biodiversity.
Hotspots of biodiversity are areas of high biodiversity which are rich in endemic species but are threatened due to human encroachments. India has three hotspots — Western ghats, Indo-Burma and Himalaya.
Biodiversity found in India and the endemism of hot spot are nature's bounty to the country. It should be protected and saved from destruction by human greed.

Multiple Choice Questions (With Answers)

- (1) The Earth Summit held at Rio de Janeiro in 1992 resulted into (a) Computation of Red List (b) Establishment of Biosphere Reserves (c) Convention on Biodiversity (d) IUNC. (NCERT)
- (2) Approximate percentage of endemic flowering plants in India is (a) 23 (b) 33 (c) 53 (d) 63. (NCERT)

- (3) An *ex situ* conservation method for endangered species is (a) National Parks (b) Cryopreservation (c) Wildlife Sanctuary (d) National Park, Sanctuary and Biosphere Reserve. (AIIMS 2008)
- (4) World summit on sustainable development of 2002 was held in (a) South Africa (b) Sweden (c) Argentina (d) Brazil. (CBSE 2008)
- (5) Ten species (i) to (x) sampled in four areas A–D having 11–13 habitats (given in brackets) possess populations (in thousands) given in the table. Which one has the maximum species diversity

		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
A	(11)	2.3	1.2	0.52	6.0	–	3.1	1.1	9.0	–	10.3
B	(11)	10.2	–	0.62	–	1.5	3.0	–	8.2	1.1	11.2
C	(13)	11.3	0.9	0.48	2.4	1.4	4.2	0.8	8.4	2.2	4.1
D	(12)	3.2	10.2	11.1	4.8	0.4	3.3	0.8	7.3	11.3	2.1

- (a) A (b) B (c) C (d) D

(CBSE 2008)

- (6) Core, buffer and manipulation zones are found in (a) National Park (b) Biosphere reserve (c) Sanctuary (d) Tiger reserve. (MP PMT 2009)
- (7) Chipko movement was launched for protection of (a) Forests (b) Grasslands (c) Wetlands (d) Livestock. (CBSE 2009)
- (8) Hotspots of biodiversity are (a) Areas of Earth that contain many endemic species (b) Species serves as proxy for entire communities in particular areas (c) Species in particular niche (d) Species diversity at particular area. (DPMT 2010)
- (9) Which one of the following is an example of *ex situ* conversation (a) Sacred groves (b) National Park (c) Wildlife sanctuary (d) Seed bank. (CBSE 2010)
- (10) Which one has the highest number of species ? (a) Birds (b) Angiosperms (c) Fungi (d) Insects (CBSE 2011)
- (11) Biodiversity of a geographic region represents (a) Genetic diversity present in the dominant species of the region (b) Species evdemism to the region (c) Endangered species found in the region (d) Diversity in organisms living in the region. (CBSE Mains 2011)
- (12) A hotspot of biodiversity in India is (a) Eastern Ghats (b) Western Ghats (c) Gangetic plain (d) Sunderbans. (CBSE 2012)
- (13) Select the correct statement about biodiversity (a) large scale planting of Bt cotton has no adverse effect on biodiversity (b) conservation of biodiversity is a fad pursued by developed countries (c) desert areas of Rajasthan and Gujarat have a very high level of desert animal species as well as numerous rare animals (d) Western Ghats have a very high degree of species richness and endemism. (CBSE Mains 2012)
- (14) Which of the following represent maximum number of species among global biodiversity (a) Mosses and ferns (b) Algae (c) Lichens (d) Fungi. (NEET 2013)
- (15) Which is not used for *ex situ* plant conservation (a) Botanical gardens (b) Field gene banks (c) Seed banks (d) Shifting cultivation. (NEET 2013)
- (16) The concept of hotspots was give given by (a) Myers (b) Mayer (c) Simpson (d) David. (WB 2014)
- (17) An example of *ex situ* conservation is (a) Sacred grove (b) National Park (c) Seed bank (d) Wildlife sanctuary. (CBSE 2014)
- (18) Which of the following is not an *ex-situ* conservation ? (a) Botanical garden (b) Biosphere reserve (c) Seed bank (d) Cryopreservation. (KCET 2015)
- (19) An area is declared as 'hot spot' when (a) it has 1500 or more endemic species and 75% of its orginal habitat is lost (b) it has 1500 or more vertebrate species and 75% of its original habitat is lost (c) it has more than 2000 species of plants (d) most of the species inhabiting the area are facing the risk of extinction. (CBSE 2015)
- (20) Which is the national aquatic animal of India (a) Sea horse (b) Gangetic shark (c) River Dolphin (d) Blue Whale. (NEET-I 2016)
- (21) Which of the following National Parks is home to the famous deer Hangul (a) Dachigam National Park, J and K (b) Keibul Lamjao National Park, Manipur (c) Bandhavgrah National Park, Madhya Pradesh (d) Eaglenest Wildlife Sanctuary, Arunachal Pradesh. (NEET-II 2016)

- (22) Which one of the following is related to *ex situ* conservation of threatened animals and plants ?
 (a) Wildlife safari parks (b) Biodiversity hotspots (c) Amazon rainforest (d) Himalayan region. (NEET 2017)
- (23) The region of biosphere reserve which is legally protected and where no human activity is allowed is known as (a) core zone (b) buffer zone (c) transition zone (d) restoration zone. (NEET 2017)

Assertion Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—

- (a) If both A and R are true and R is the correct explanation of A
 (b) If both A and R are true and R is not the correct explanation of A
 (c) If A is true but R is false
 (d) If both A and R are false.

- Assertion: Genetic diversity within species increases with the increase in habitat variations.
 Reason: It is essential for adaptation to varied environments.
 A B C D
- Assertion: Hot spots are areas which have been degraded beyond repair.
 Reason: There has been adverse changes in environment.
 A B C D
- Assertion: Tropical rain forests are disappearing fast from developing countries such as India.
 Reason: No value is attached to these forests because these are poor in diversity. (AIIMS 2007)
 A B C D
- Assertion: Now-a-days, biodiversity is declining with an accelerated rate.
 Reason: Exotic species are considered to be major cause of extinction of species. (AIIMS 2014)
 A B C D

ANSWERS

8. Match the Columns — (i)–(c), (ii)–(e), (iii)–(a), (iv)–(b).

Multiple Choice Questions

- (1) —c (2) —b (3) —b (4) —a (5) —d (6) —b (7) —a (8) —a (9) —d (10) —d
 (11) —d (12) —b (13) —d (14) —d (15) —d (16) —a (17) —c (18) —b (19) —a (20) —c
 (21) —a (22) —a (23) —a

Assertion Type Questions

- (1) —A (2) —D (3) —C (4) —B

Pollution is an undesirable change in physical, chemical or biological characteristics of environment air, water, soil and land that has the potential to adversely affect human life, the lives of the desirable species, natural resources, industrial processes, and cultural assets.

Basic Cause of Pollution. There are an ever increasing rise in human population that is, putting an equally increasing demand for more food, water supply, roads, transportation, dwelling units, schools, hospitals, electricity, automobiles, more industrial products and a large number of other commodities. This is putting pressure on natural resources which are, therefore, undergoing depletion and degradation. It results in pollution of air, water and soil. Pollution is different from **contamination** which is the presence of harmful organisms or their products causing disease or discomfort. Pollution can be **natural** or **man made**. Natural pollution comes from natural sources like release of methane by arctic chimneys, cattle and paddy fields, carbon monoxide from plants and animals, dust storms, nitrogen oxides, ozone, volcanic eruptions, emission of natural gas, soil erosion, ultraviolet rays, cosmic rays, etc. 99.95% of pollution is natural. **Man made** or **anthropogenic pollution** is the pollution caused by human activities like sewage, emissions, effluents, pesticides, fertilizers, mining, burning of fossil fuels, noise, etc. Only 0.05% of pollution is anthropogenic. However, it is quite harmful as it is concentrated in certain localities. Human activities are also causing changes in lower atmosphere (troposphere and stratosphere) like increased concentration of CO_2 and other green house gases in troposphere and depletion of ozone in the stratosphere.

Classification of Pollutants. Pollutants are substances, chemicals or factors that have the potentiality to adversely affect human beings, human assets, natural resources and natural characteristics of the environment. They are classified into different ways.

1. Depending upon **unchanged** or **changed nature**, pollutants can be primary or secondary.

(i) **Primary Pollutants.** Pollutants persisting in the environment in the form they are passed into it, *e.g.*, DDT, CO_2 , SO_2 , flyash.

(ii) **Secondary Pollutants.** Pollutants which are formed by reaction amongst the primary pollutants. For example, O_3 and peroxyacyl nitrates (PAN) are formed through reaction between nitrogen oxides and hydrocarbones in the presence of sunlight. Secondary pollutants are often more harmful than primary pollutants. The enhanced effect is called **synergism**.

Differences Between Primary and Secondary Pollutants

Primary Pollutants	Secondary Pollutants
<ol style="list-style-type: none"> 1. They are pollutants which are passed into environment in the form they are produced. 2. They belong to various categories like particulate, aerosol, reduced, oxidized. 3. They are less toxic. 4. They do not show synergism. 5. Primary pollutants persist in the form they are released in the environment. 	<ol style="list-style-type: none"> 1. The pollutants develop as a result of interaction of primary pollutants and environmental constituents. 2. They are generally oxidizing. 3. They are more toxic. 4. Secondary pollutants show synergism. 5. They are modified products.

2. According to their nature or quantity, the pollutants may be quantitative or qualitative.

(i) **Qualitative Pollutants.** They are harmful products which function as pollutants due to their nature. Qualitative pollutants normally do not occur in the environment but are passed into it through human activity, e.g., DDT and other pesticides, fungicides, herbicides, etc.

(ii) **Quantitative Pollutants.** They become pollutants only when their concentration reaches beyond a threshold value in the environment, e.g., CO, CO₂, nitrogen oxides.

3. According to their degradability, pollutants are of two types, degradable or nondegradable.

Degradable Pollutant. The pollutant degrades after some time either automatically (e.g., heat) or through the agency of microorganisms (= biodegradable, e.g., sewage, live-stock wastes, market garbage). Biodegradable pollutants are disposed off through natural processes as well as waste treatment plants. Because of the presence of biogenetic nutrients and energy, they can be turned into a resource, e.g., compost, manure, biogas.

Nondegradable Pollutant. The pollutant does not get degraded or broken down naturally into harmless materials, e.g., DDT (dichloro-diphenyl trichloro-ethane), BHC (benzene hexachloride), empty cans, polythene bags, waste plastics. Nondegradable pollutants are also called **persistent pollutants**. They are difficult to manage as a natural method of degradation is absent. The term **nonbiodegradable** is also used as microorganisms are unable to degrade them.

Differences Between Biodegradable and Nonbiodegradable Pollutants

Biodegradable Pollutants	Nonbiodegradable Pollutants
<ol style="list-style-type: none"> 1. They are those pollutants which are decomposed and degraded by microbes. 2. The pollutants are degraded quite rapidly. 3. Biodegradable pollutants do not pile up. 4. They can be used to produce energy, manure, compost and biogas. 5. They become part of rapid turnover in biogeochemical cycles. <p>Examples : Garbage, Sewage, Livestock, wastes.</p>	<ol style="list-style-type: none"> 1. The pollutants are not decomposed by microbes. 2. They are degraded extremely slowly. 3. Nonbiodegradable pollutants often accumulate. 4. Some of the pollutants, if properly separated, can be recycled. Others are not manageable. 5. Many of them do not enter biogeochemical cycles. Others are very slow and often toxic. <p>Examples: DDT, BHC, plastics, polyethylene, cans, broken glass, etc.</p>

Types of Pollution

1. On the basis of physical nature of the pollutants, pollution can be (i) gaseous pollution (ii) dust pollution (iii) thermal pollution (iv) noise pollution (v) radioactive pollution.
2. On the basis of emission of pollutants, pollution can be
 - (i) **Point Source Pollution.** Pollutants are released from a single point, e.g., chimney, municipal sewer.
 - (ii) **Line Source Pollution.** Pollution is passed along a narrow belt, e.g., roads due to automobile exhausts.
 - (iii) **Area Source Pollution,** e.g., mining area, industrial estate.
 - (iv) **Diffuse Source Pollution.** It is over a large area, e.g., sprayed pesticides or fertilizers through run-off.
 - (v) **Fixed Source Pollution.** Pollutants are passed from fixed spots as of large factories, small scale industries, mineral smelters, electrical power plants.
 - (vi) **Mobile Source Pollution.** Pollutants come out from a moving structure like transport vehicles.

I. AIR/ATMOSPHERIC POLLUTION — Sources, Types and Effects

Definition

Air pollution is the addition of particles, gases and chemicals into the atmosphere that have the potential to adversely affect human health, health of animals, vegetation, natural resources and human assets. Substances and factors which cause air pollution are called **air pollutants**. Air pollution is both **natural** and **anthropogenic**. Though anthropogenic air pollution is less than 1% of the total, it is proving to be more harmful due to its higher concentration in the area of its formation. It comes from both **mobile** and **fixed** sources. Air pollutants coming directly from the pollution sources are called **primary air pollutants**. Reaction between two or more primary air pollutants gives rise to **secondary air pollutants**.

Causes of Air Pollution

The various **causes of air pollution** are

- (i) **Combustion** of natural gas, petroleum, coal and wood in industries, automobiles, aircrafts, railways, thermal plants, agricultural burning, kitchens, etc, (soot, flyash, CO_2 , CO, nitrogen oxides, sulphur oxides).
- (ii) **Metallurgical processing** (mineral dust, fumes containing fluorides, sulphides and metallic pollutants like lead, chromium, nickel, beryllium, arsenic, vanadium, cadmium, zinc, mercury).
- (iii) **Chemical industries** including pesticides, fertilizers, weedicides, fungicides.
- (iv) **Cosmetics.**
- (v) **Processing industries** like cotton textiles, wheat flour mills, asbestos.
- (vi) **Welding, stone crushing, gem grinding,** etc.

Natural air pollutants include (a) pollen, spores, (b) marsh gas, (c) volcanic gases and (d) synthesis of harmful chemicals by electric storms and solar flares. The major cause of pollution in the **urban areas** is automobiles which inefficiently burn petroleum, release 75%

of noise and 80% of air pollutants. Concentration of industries in one area is another major cause of air pollution, e.g., cotton dust in Ahmedabad, Surat and nearby areas.

(i) Degree of atmospheric pollution depends upon the total mass of pollutants emitted and the conditions of the atmosphere that determine their fate and transport. It is, however, seldom high because major part of air is O_2 , N_2 , CO_2 and water vapours. Pollutants are only a fraction of 1% but even in small concentration they are extremely harmful to life and property.

(ii) 52% of air pollution is caused by CO , 18% by SO_2 , 12% by hydrocarbons, 10% by particulates, 6% by nitrogen oxides and 2% by the remaining.

Primary Air Pollutants and their Effects

The major primary air pollutants are particulate matter, carbon monoxide, CO_2 , H_2S , hydrocarbons, sulphur dioxide, nitrogen oxides, etc.

1. **Particulate Matter.** It consists of soot, flyash, dusts of various types, fur, hair, spores, pollen grains, etc. Particulate matter is differentiated into **settleable** (larger than $10\ \mu m$, remaining in air for less than one day) and **suspended** (less than $10\ \mu m$ remaining in air for more than one day to several weeks). **SPM** (suspended particulate matter) is maximum in Delhi (Linfen in China is the most polluted city of the world). It is differentiated into **aerosol** (less than $1\ \mu m$), **dust** (more than $1\ \mu m$) and **mist** (liquid, more than $1\ \mu m$). **Smoke** is similar to dust but consists of visible suspension of carbon and other particles given off by burning or smouldering organic matter. Particles of $2.5\ \mu m$ and lesser diameter (PM 2.5) are the most harmful to human health (Central Pollution Control Board or CPCB). They pass deep into the lungs causing breathing and respiratory problems, irritation, inflammation and damage to lungs resulting in pre-mature death. (i) **Soot** (incomplete burning of carbohydrates), **smoke**, **flyash** (fine particulate matter passed out alongwith gases during burning of coal) and **dust** deteriorate the quality of articles, clog stomata, cover leaf surface, produce allergic reactions, especially bronchial asthma and chronic bronchitis. (ii) Particulate matter from processing industries (e.g., cotton dust, iron mill dust, mine dust, flour mill dust, gem grinding, cement industry, asbestos industry) causes **pneumoconiosis**, **byssinosis**, **emphysema**, **siderosis** and other pulmonary problems. (iii) Dust and smoke produce **smog**. (iv) Pesticide rich mist. (v) Dust containing heavy metals like (Hg, Pb, Cu, Fe). (vi) Pollen and dust mites. All of these cause respiratory problems. Sometimes the particulates accumulate in upper layers of atmosphere to form large coloured clouds that hinder passage of solar radiations, lower temperature of earth's surface and bring about changes in the thermal budgets of atmosphere.

2. **Carbon Monoxide.** It is produced due to incomplete combustion, metallurgical operations and naturally by plants as well as animals. 50% emissions are from automobiles. Cigarette smoke also contains a lot of CO . Normally CO has a brief residence in atmosphere and gets oxidised to CO_2 . However, in congested and closed areas it proves quite harmful. Carbon monoxide combines with haemoglobin, produces **carboxyhaemoglobin** or $COHb$. At 50 ppm, CO converts 7.5% of haemoglobin into carboxy-haemoglobin within 8 hours. It impairs oxygen transport resulting in giddiness, headache, decreased vision, cardiovascular malfunction and asphyxia.

3. **Carbon Dioxide.** It is a green house gas, the concentration of which is constantly rising from 280 ppm in 1750 to 368 ppm in 2000 and 380 in 2007. In excess it causes headache and nausea.

4. **H₂S.** It is a product of putrefaction, treatment of sulphur containing ores, refineries, chemical plants and bituminous fuels. It causes mottled chlorosis and defoliation in plants, decolourises paints, produces eye irritation, throat irritation and nausea.

5. **Hydrocarbons (HCs) or Volatile Organic Carbons (VOCs).** They are produced naturally (e.g., marsh gas) as well as due to incomplete combustion. Hydrocarbons, especially polynuclear aromatic (with 2 or more fused benzene rings) or PAH and formaldehyde are carcinogenic, cause irritation of eyes and mucous membrane and bronchial constriction. There is increased mucus secretion and tearing of alveoli. Formaldehyde is also produced from indoor sources like newly manufactured carpets. Hydrocarbons give rise to secondary pollutants or photochemical oxidants with nitrogen oxides. Methane (marsh gas) is produced naturally during decomposition of organic matter, paddy fields (40% of the total), cattle and incomplete combustion in automobiles, industries, kitchens etc. It is being emitted from underground reservoirs in the arctic regions. Methane is a green house gas which is oxidised in the atmosphere to CO₂.

6. **Sulphur Oxides.** They occur mostly in the form of sulphur dioxide. It is produced in large quantity during smelting of metallic ores (e.g., iron, copper, lead, zinc, nickel, etc) and burning of petroleum and coal in industries, thermal plants, homes and motor vehicles. In the air, SO₂ combines with water to form sulphurous acid (H₂SO₃). It is the cause of acid rain. The dreadful British smog of 1952 contained SO₂. The different effects of sulphur dioxide include :

(i) It causes chlorosis and necrosis of vegetation in as low concentration as 0.032 ppm. Lichen vegetation (e.g., *Paramelia*, *Usnea*, *Cladonia*) and mosses are completely destroyed. Garden pea is another SO₂ pollution indicator. Besides chlorosis, SO₂ causes membrane damage, metabolic inhibition, growth and yield reduction. Chlorosis results from destruction of chlorophyll which is changed to phaeophytin (Roy and Le Blanc, 1966, 1967).

The leaves often assume water-soaked appearance. Monocotyledons are more sensitive. Therefore, cereal crops are damaged in the area around smelters and industrial belts. Coniferous forests, apple and mango orchards are also destroyed.

(ii) Sulphur dioxide, above 1 ppm, affects human beings. It causes irritation to eyes and injury to respiratory tract (asthma, bronchitis, emphysema). Hicky (1971) believes that SO₂ pollution is related to higher death rate in aged persons. It kills fish and other animal life. Brehm (1976) has recorded the destruction of fish from thousands of lakes and rivers of Scandinavia due to SO₂.

(iii) It results in discolouration and deterioration of buildings, sculptures, painted surfaces, fabrics, paper, leather, etc. The reported threat to Tajmahal of Agra from nearby refinery of Mathura is on account of it.

(iv) SO₂ corrodes metals like iron and zinc. Therefore, it impairs electrical and other metallic equipment.

(v) The compound has mutagenic properties.

7. **Nitrogen Oxides.** They are produced naturally through biological and nonbiological activities from nitrates, nitrites, electric storms, high energy radiations and solar flares. Human activity forms nitrogen oxides in combustion process of industries, automobiles, incinerators and nitrogen fertilizers. Nitrogen oxides produce **brown air** or reddish brown haze. The important effects of nitrogen oxides (N₂O, NO, NO₂, N₂O₄, N₂O₅) are as follows:

(i) They act on unsaturated hydrocarbons to form peroxyacylnitrates or PAN.

(ii) Nitrogen oxides give rise to photochemical smog.

- (iii) In the presence of moisture, nitrogen oxides have a corrosive effect on metals.
- (iv) They cause fading and deterioration of different types of textiles.
- (v) Nitrogen oxides produce lesions, necrosis, defoliation, die back and death of many plants.
- (vi) They cause eye irritation, respiratory troubles, lung edema, blood congestion and dilation of arteries. At a concentration of 15—50 ppm, nitrogen oxides are known to bring about injury to lungs, liver and kidneys. They are suspected to produce cancer.
- (vii) The oxides possess mutagenic properties.
- (viii) Nitrogen oxides (NO_2) are formed in the stratosphere due to solar flares. Large flares shall form enough oxides to act upon and destroy the protective ozone layer.

8. **Fluorides.** They are given out during refining of minerals (*e.g.*, aluminium, also from ground water). Fluorides cause **fluorosis**. In plants there is chlorosis and necrosis of leaf tips and leaf margins, followed by abscission. In animals, fluorides bring about abnormal calcification of bones and teeth (making them weak), frequent diarrhoea and swelling of knee bones. In humans there is mottling of teeth, weak bones, boat-shaped posture, knocking knees, gastrointestinal and neuromuscular disorders.

9. **Chlorofluorocarbons/Chlorofluoromethane/Freon/Aerosols.** They are chemicals used as refrigerants, propellants and solid plastic foams. The chemicals are released as aerosol by jets flying at high altitudes. Along with nitrogen oxides, chlorofluorocarbons react with ozone of ozonosphere and deplete the same. Hole in the ozone shield over antarctic region has widened from 129 to 133 dobson units in 1994 alone. This can increase the amount of ultraviolet radiations reaching the earth.

10. **Other Atmospheric Pollutants.** Mercury (burning of coal, smelting), methyl isocyanate (pesticide manufacture), phosgene (pesticide manufacture, dye industry), ammonia (fertilizer, dye and lacquer industries) and lead (automobile exhausts) are pollutants added to atmosphere though they may not reside there (*e.g.*, lead in soil). **Bhopal gas tragedy** (Dec, 1984) was due to release of phosgene and methyl isocyanate.

11. **Automobile Exhausts.** Automobiles burn petroleum inefficiently causing 80% of air pollution and 75% of noise pollution in urban areas. They release hydrocarbons (13.7%), carbon monoxide (77.2%), nitrogen oxides (7.7%), sulphur oxides, ammonia, aldehydes and lead (90% of total lead poisoning). Lead is present in petroleum in the form of $\text{Pb}(\text{CH}_3)_4$ and $\text{Pb}(\text{C}_2\text{H}_5)_4$ as antiknock agent.

Secondary Air Pollutants and their Effects

They are usually produced photochemically from primary pollutants and are called photochemical oxidants. Secondary air pollutants occur in one type of smog called photochemical smog.

12. **Smog** (Des Voeux, 1905). Smog is opaque or dark fog having condensed water vapours, dust, smoke and gases (SO_2 , H_2S , NO_2 , etc.). It causes silvering/glazing and necrosis in plants, allergies and asthma/bronchitis in humans. Some famous smogs of the world are Los Angeles smog (1946), London smog (1952), Tokyo smog (Rome, New York, Sydney, 1970). Smog is of two types :

(i) **Classical (London) Smog.** It occurs at low temperature, contains sulphur gases (hydrogen sulphide, sulphur dioxide), smoke and dust particles. Classical smoke has reducing environment. It is dark brown and opaque. This type of smog is formed by condensation

of water vapours with H_2S and SO_2 over dust or smoke particles. Secondary pollutants are absent. Classical smog occurred in London during December, 1952, when it affected 50% of population and killed over 4000 persons.

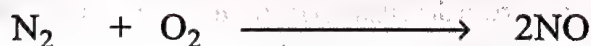
(ii) Photochemical (Los Angeles) Smog.

It is a grey or yellowish brown opaque smog having oxidising environment but little smoke. Photochemical smog contains secondary pollutants or photochemical oxidants. It was first reported over Los Angeles in 1940s. Photochemical smog is formed at high temperature over cities and towns due to still air, emission of nitrogen oxides and carbohydrates from automobile exhausts and solar energy. Nitrogen dioxide splits into nitric oxide and nascent oxygen. Nascent oxygen combines with molecular oxygen to form ozone. Ozone reacts with carbohydrates to form aldehydes and ketones. Nitrogen oxides, oxygen and ketones combine to form peroxy-acyl-nitrates (PAN). In areas with intense solar radiations, photochemical smog forms brown air. In areas/seasons with lesser solar radiations, smog formation is incomplete. It produces grey air.

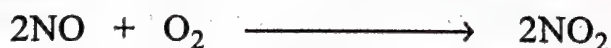
Ozone reacts with carbohydrates to form aldehydes and ketones. Nitrogen oxides, oxygen and ketones combine to form peroxy-acyl-nitrates (PAN). In areas with intense solar radiations, photochemical smog forms brown air. In areas/seasons with lesser solar radiations, smog formation is incomplete. It produces grey air.

Photochemical Oxidants/Secondary Air Pollutants. They are secondary pollutants (ozone, peroxyacyl nitrates, aldehydes and phenols) produced due to photochemical reactions between nitrogen oxides and unsaturated hydrocarbons.

Reaction inside Engine



Reaction in Atmosphere



Photochemical Reactions



Fig. 16.1. Effect of PAN over Milkweed

(i) **Ozone.** Being strong oxidant it destroys chlorenchyma, produces necrosis, hardens rubber, damages textiles, corrodes surface of marble statues and heritage buildings, injures mucous membranes, dry throat, haemorrhages and eye irritation.

(ii) **Peroxy-acyl Nitrates (PAN, also PBN, PPN).** They damage chloroplasts, inhibit electron transport system and spoil enzyme systems controlling cellular metabolism. Young and spongy parenchyma cells are destroyed resulting in silvery, glazing, bronzing and necrosis in leaves. In human beings they cause respiratory distress and eye irritation.

(iii) **Aldehydes.** Irritation in gastro-intestinal and respiratory tracts.

(iv) **Phenols.** Damage to kidneys, liver, spleen and lungs.

13. Pollen and Microbes. They are normal constituents of air. Excess of them are produced in certain seasons. Microbes directly damage the vegetation, food articles and cause diseases in plants, animals as well as human beings. Excess of pollen causes allergic reactions in several human beings. The common reactions are asthma, bronchitis and rhinitis. They are collectively called **hay fever**. The important allergic pollen belong to *Amaranthus spinosus*, *Chenopodium album*, *Cynodon dactylon*, *Ricinus communis*, *Sorghum vulgare*, *Prosopis chilensis*.

TABLE 16.1 : Effects of Air Pollution on Man, Vegetation and other Materials

Pollutant	Effects on Man	Vegetation, and other Materials
Carcinogenic hydrocarbon	On man	Cancer
Carbon monoxide	On man	Poisoning, increased accident liability
Dust	On man	Respiratory diseases, diseases like silicosis (cough, cold, sneezing, allergic diseases, etc.), asbestosis, byssinosis, poisoning from metallic dust.
Hydrogen sulphide	On man	Irritation of respiratory passages, danger of respiratory paralysis and asphyxiation.
	On materials	Darkening of painted surfaces, corrosion.
Hydrogen fluoride	On man	Irritation, diseases of bone (fluorosis), mottling of teeth, respiratory diseases.
	On vegetation	Destruction of crops.
Heavy metals	On man	Specific poisoning, retardation of activities of brain, interference in enzyme activities in liver & kidney.
Nitrogen dioxide	On man	Irritation, bronchitis, oedema of lungs.
Photochemical	On man	Lung irritation, asthma, bronchitis, etc.
Smog (oxidants)	On vegetation	Destruction of vegetation.
	On materials	Deterioration of rubber products such as tyres and insulating wires.
Sulphur dioxide	On man	Suffocation, irritation of throat and eyes, respiratory diseases.
	On vegetation	Destruction of sensitive crops and reduced yield.
	On materials	Corrosion.

Control of Air Pollution

It can be achieved by (i) Low sulphur fossil fuel. (ii) Reduction in emissions. (iii) Zoning of industries away from human settlements for dispersing pollution sources. (iv) Destroying pollutants by thermal or catalytic combustion. (v) Changing pollutants to less toxic forms. (vi) By precipitation of pollutants.

Control of Particulate Matter. It is carried out by two types of devices, arresters and scrubbers.

(i) **Arresters.** They are devices to separate particulate pollutants. Arresters are of various types. (a) **Cyclonic Separators.** The particulate rich air is passed into a chamber where it is rotated. Centrifugal force causes settling of particulates while clean air is allowed to pass out. (b) **Trajectory Separators.** Dirty air is thrown into a collecting chamber in the form of an oblique jet. Heavier particles settle down. (c) **Gravity Settling Chamber.** Dirty air is passed through a large chamber. Particulates settle down while cleaner air passes out.

(d) **Filters.** They are large sized porous bags of polyester, polypropylene, polyamide, teflon, etc. through which dry emissions are passed under pressure to filter out particulate matter.

(e) **Electrostatic Precipitators (ESPs).** They are the most efficient devices where particles present in dirty air are charged electrically to form a corona of negative charges around them. The charged dust particles are passed over collection plates connected electrically with earth. Dust particles lose their charge and settle down.

(ii) **Scrubbers.** Dust separation is also carried out by scrubbers. They are of two types, dry and wet. Both can be used to separate particulate matter by passing through dry or wet packing material but more commonly they are employed in removing gaseous pollutants.

Control of Gaseous Pollutants

Gaseous pollutants are removed from emissions by three methods—combustion, absorption and adsorption.

(i) **Combustion Technique.** It is applicable to oxidisable pollutants. The emissions are burnt at high temperature. The process is used in petrochemical, fertilizer, paint and varnish industries.

(ii) **Absorption Technique.** The technique uses scrubbers having packing material where gaseous pollutants are absorbed. A fine spray of water dissolves ammonia, sulphur dioxide and nitrogen oxides. Calcium hydroxide or a bed of lime is used to absorb SO_2 .

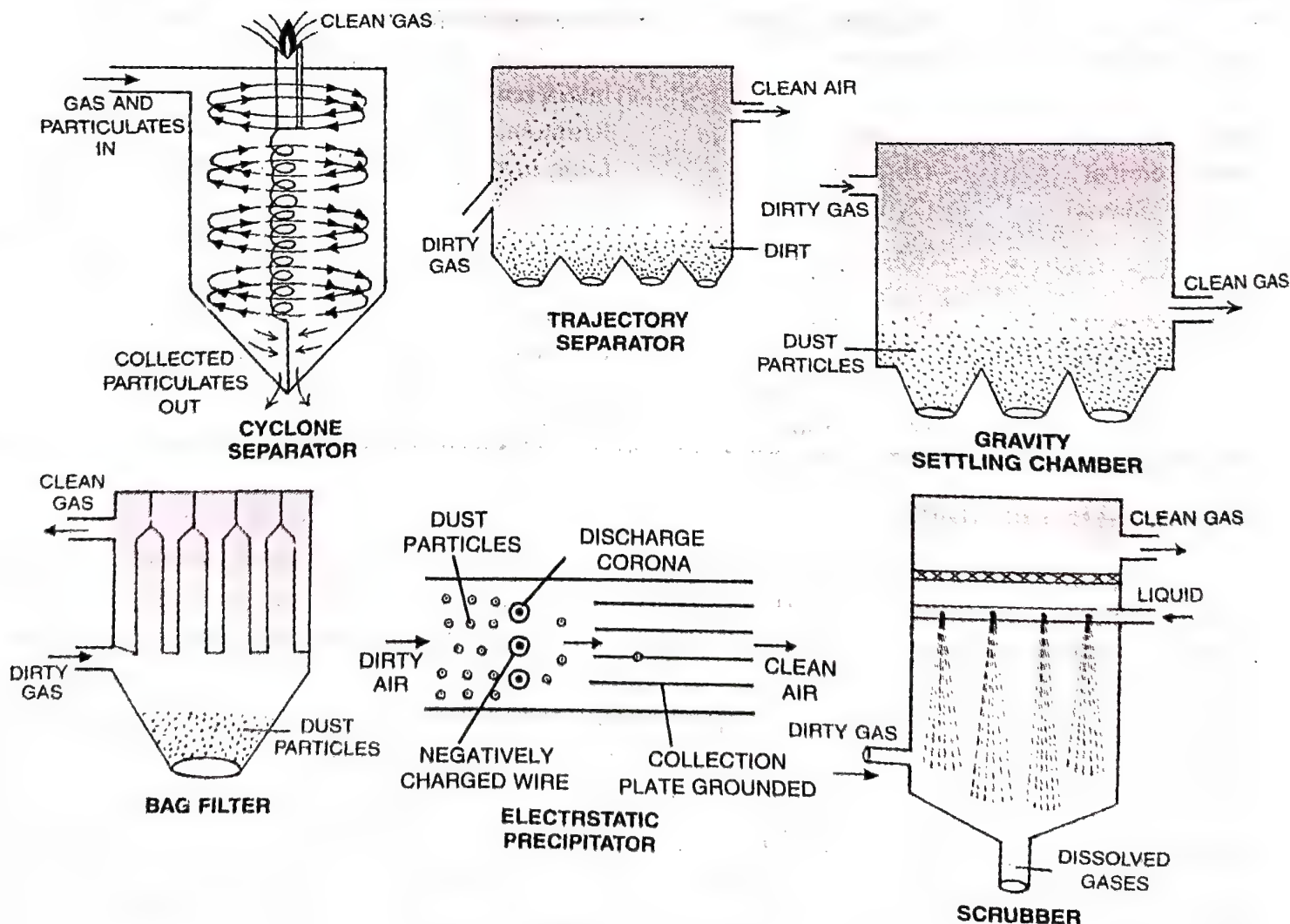


Fig. 16.2. Devices to control air pollution.

(iii) **Adsorption Technique.** Here very fine solid particles, (e.g., activated charcoal) are used to remove toxic gases, vapours, inflammable compounds. Some specific methods are as follows :

1. **Automobiles.** (i) Two-stroke engines fitted in two wheelers (waste fuel 20–30%) be changed to either four-stroke engines or fitted with catalytic converters specially designed for them. (ii) Use of multipoint fuel injection engines. (iii) Leaded petrol be replaced with unleaded one and diesel with low sulphur diesel. (iv) Tune-ups (for high air-fuel ratio) and catalytic converters. Catalytic converters have costly metals like platinum-palladium and rhodium as catalysts. Exhaust gases first pass through catalytic converter. Hydrocarbons which have been left unburnt are oxidised to produce carbon dioxide and water. Carbon monoxide is also oxidised to form carbon dioxide. However, nitrogen oxide splits up to form nitrogen gas.



Automobiles fitted with catalytic converter should not use leaded petrol because lead inactivates the catalyst of the converter. (v) Periodic check up of pollution control for all vehicles. Use of CNG (compressed natural gas) decreases the amount of pollutants in automobile exhausts.

2. **Begasse and Rice Husk.** Begasse should not be used as fuel. Rice husk should be first converted into briquettes.

3. **Fly Ash.** About 38% fly ash is produced by coal based thermal plants. It should be removed through wet method and used in building material.

4. **Industrial Pollution.** Smokestacks or chimneys of various industries, smelters and thermal power plants give out a lot of smoke, containing particulate and gaseous air pollutants. The emission also possesses hot air with harmless gases like nitrogen and oxygen. The various methods of control of air pollution caused by industries are : (i) **Tall Chimneys.** They disperse smoke more thoroughly. (ii) **Gravity Settling Chambers.** Particles larger than 50 μm settle down. (iii) **Wet Scrubbers.** A fine spray of water or alkaline fluid like lime is allowed to fall over exhaust emissions. Water dissolves gases. The particles also become heavy and fall down. Lime reacts with sulphur dioxide to produce a precipitate of calcium sulphate or calcium sulphite is used to remove soluble gases and particles. (iv) **Bag Filters.** Porous bags of teflon or polyester filter out particulate matter. (v) **Cyclone Collectors.** They cause settling down of particulate matter through centrifugation. (vi) **Electrostatic Precipitators (ESPs).** They are very efficient devices which remove 99% of particulates present in the industrial and thermal plant exhausts. There are electrode wires and a stage of collecting plates. The collecting plates are connected with ground. The electrode wires are provided with several thousand volts electric current. It creates a corona which releases electrons. The electrons attach to the suspended particles and make them negatively charged within a fraction of a second. Air with charged particles passes slowly over collecting plates. The particulate matter settles over them and are removed.

5. **Vegetation.** A broad strip of vegetation or **green strip** along roads and around industrial areas reduces particulate pollution. Vegetation can also metabolise toxic gases like CO (e.g., *Ficus variegata*, *Coleus*, *Daucus*, *Phaseolus*) and nitrogen oxides (e.g., *Vitis*, *Pyrus*, *Robinia*, *Rhamnus*).

Controlling Vehicular Air Pollutants

(Case Study of Delhi)

Delhi has the maximum number of vehicles in India. In 1990 the total number of cars in Delhi were more than the combined number for the states of West Bengal and Gujarat. Since 80% of air pollution in urban areas is due to automobiles, Delhi used to rank fourth amongst the 41 most polluted cities of the world. The problem of air pollution was so serious that most Delhites began to complain of burning eyes and respiratory discomforts. A public interest litigation (PIL) was filed in Supreme Court. The Supreme Court directed the government to take appropriate measures for reducing pollution caused by automobiles through

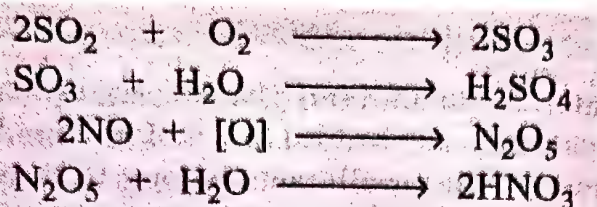
- (i) Switch over of public transport from diesel/petrol to CNG
- (ii) Phasing out of old vehicles
- (iii) Compulsory use of unleaded petrol and reduced sulphur content of diesel.
- (iv) Compulsory regular check up of pollution emission of vehicles and enforcement of euro II norms
- (v) Fitting the vehicles with catalytic converters.

Delhi became the first city of the world to use CNG for its public transport system and autorickshaws by the end of 2002. CNG (**compressed natural gas**) is a better fuel than petrol or diesel because it is (a) Cheaper (b) Burns more efficiently (c) Does not produce much pollution (d) Cannot be siphoned off by thieves (e) Cannot be adulterated like petrol and diesel. The major problem of CNG is laying down of pipes to ensure uninterrupted supply to CNG pumps or distribution points.

Because of the above mentioned measures adopted by the Government, the air quality of Delhi has improved with a substantial fall in SO_2 , CO, NO_x level between 1997-2005. However, the number of vehicles is rising rapidly in Delhi and other cities. CNG is not available everywhere. Therefore, Government of India has formulated a **new fuel policy** to reduce vehicular pollution. As per Euro II norms, sulphur content of diesel should not be more than 350 ppm while that of petrol should not be more than 150 ppm. Aromatic hydrocarbon content is pegged at 42% of fuel. These norms (initially in 11 cities) have been applicable throughout the country from 1 April 2005. From this date Euro III norms have become applicable in eleven cities — Delhi, Agra, Kanpur, Ahmedabad, Surat, Mumbai, Pune, Hyderabad, Bangalore, Chennai and Kolkata. From 1 April 2010, Euro IV norms have become applicable to thirteen cities while Euro III compliant automobiles and fuel is applicable in rest of the country from this date. Sulphur content of petrol is reduced to 50 ppm while that of diesel is to be brought down to 35 ppm.

Acid Rain

The term was coined by Robert August (1872). Acid rain is rainfall and other forms of precipitation with a pH of less than 5. pH of normal rain is 5.6 – 6.5. The most acidic rain has occurred over West Virginia U.S.A with a pH of 1.5. Acids from atmosphere are deposited over earth in two forms, wet and dry. **Wet deposition** occurs through rain, snow and fog. **Dry deposition** is settling down of wind blown acidic gases and particles over trees, various articles and soil. About 50% of acidity is passed to earth as dry deposition. Rainfall will wash it down from trees and other articles. Acid rain is caused by large scale emission of acidic gases into the atmosphere from thermal power plants, industries and automobiles. The common ones are sulphur dioxide, nitrogen oxides (NO_x), volatile organic carbons (VOCs) and hydrogen chloride. NO_x are also produced in atmosphere through lightning. Sulphur dioxide and nitrogen oxides are changed in the atmosphere into sulphuric acid and nitric acid by combining with oxygen and water.



(i) Acid rain damages plants by direct effect on foliage and growing points — chlorosis, necrosis, defoliation, dieback. (ii) It causes leaching of essential minerals of soil. (iii) Toxic minerals left in the soil further kill the plants. 50% of natural forests have been destroyed by acid rain in Germany, Sweden, north east U.S.A., Romania, Poland, etc. (iv) Acid rain has also ruined fresh water reservoirs of most industrialised countries, *e.g.*, 80% in Norway, 25% in Sweden, 20% in U.S.A. pH below 5 kills most of fish, molluscs and plankton. Acidity dissolves toxic metals like Hg, Pb, Zn, Al. Both acidity and toxic metals kill all types of aquatic life except some algae and fungi. (v) Acid rain corrodes metals, marble, painted surfaces, slate, stone, etc. The phenomenon is called **stone leprosy**. Etching of marble occurs due to conversion of calcium carbonate of marble into calcium sulphate and calcium nitrate by H_2SO_4 and HNO_3 respectively.

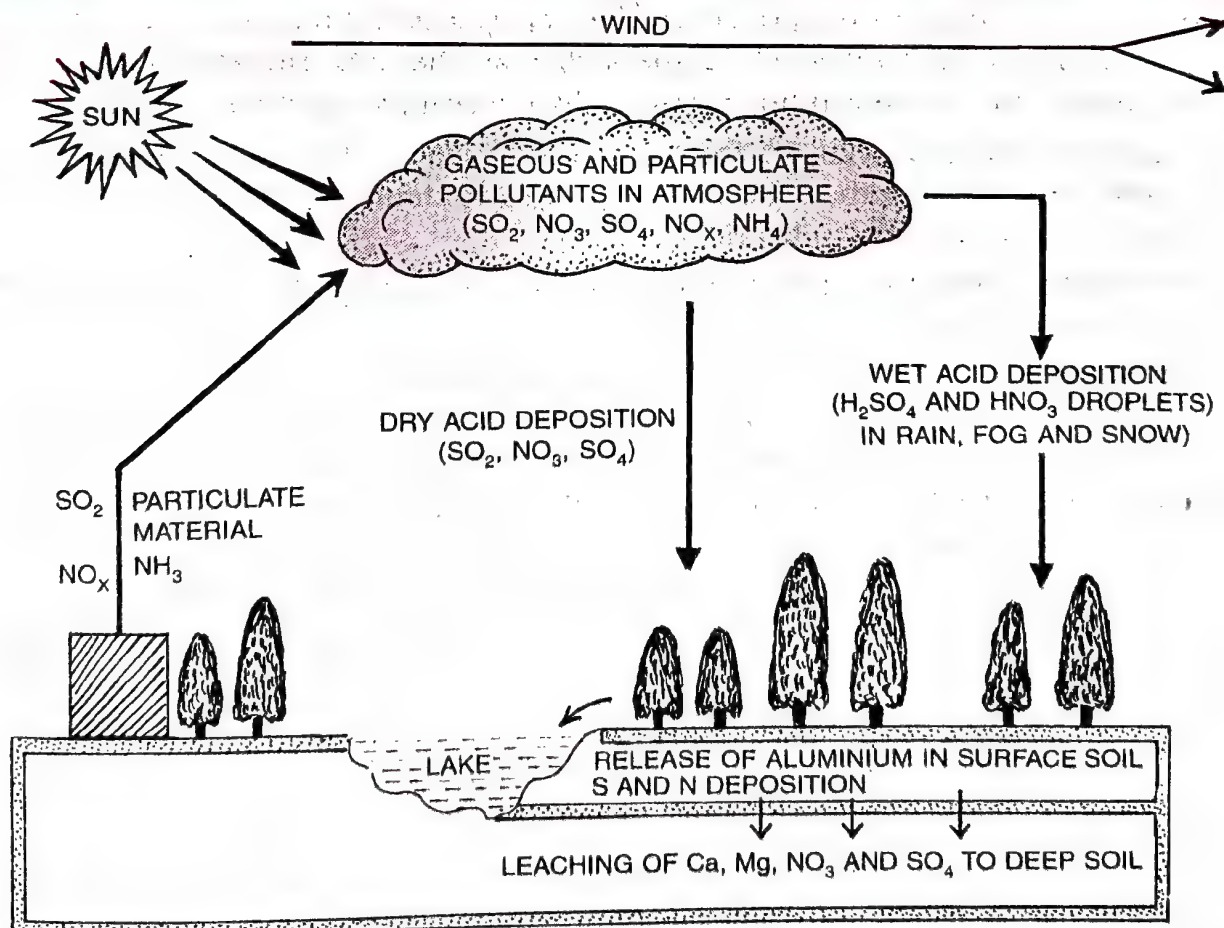
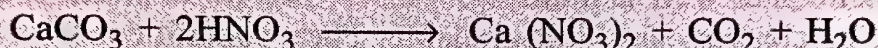


Fig. 16.3. Dry and wet acid deposition (Acid Rain)

Water Pollution

It is the degradation of quality of water due to addition of substances (inorganic, organic, biological, radiological), factors (e.g., heat) and deprivation that makes it health hazard, unfit for human use and growth of aquatic biota. Water pollutants belong to three categories — biological, chemical and physical. (i) **Biological**. Various pathogens, e.g., viruses, bacteria, protozoa, helminthes, algae. (ii) **Chemical**. Organic wastes, organic biocides (e.g., DDT, BHC) and polychlorinated biphenyls (PCBs), inorganic chemicals like As, Pb, Cd, Ni, Hg, phosphates, nitrates, fluorides, etc. (iii) **Physical**. Hot water, oil spills.

Sources of Water Pollution. They are of two types :

(a) **Natural Sources of Water Pollution.** Clay and silt from soil erosion, leaching of minerals, falling of organic matter from the banks.

(b) **Anthropogenic or Man-Made Sources of Water Pollution.** Domestic waste, sewage, soaps and detergents, run-off from agricultural fields having fertilizers and pesticides, industrial wastes, heat, waste from animal sheds and slaughter houses, oil pollution, boats, ships, etc. Due to human generated pollutants, all types of water bodies are becoming polluted — ponds, lakes, streams, rivers, canals, estuaries and oceans.

(i) **Municipal Waste Water.** It contains sewage, domestic or household wastes, detergents and some animal as well as industrial wastes. The waste water is generally passed into lakes and rivers. Its contents are biodegradable. They contain excess of phosphate and nitrate. All of them pollute water bodies.

(ii) **Industrial Waste Water.** Hot water is released by industries using steam as well as those which use water as coolant. Industrial waste waters contain a variety of organic and inorganic residues. All rivers and water bodies are heavily polluted by them. Coastal waters are polluted by prawn culture farms, fish processing and other industries.

(iii) **Surface Run Off.** Run off from agriculture land is polluted with pesticides and fertilisers. Storm water from urban and industrial sites contain a lot of biodegradable as well as toxic metals, acids and other chemicals.

(iv) **Oil Spills.** They are accidental discharges of petroleum from oil tankers, offshore oil drilling and oil refineries.

In urban areas 90% of water pollution is due to human wastes and 10% by industrial wastes. In open, 58% of all water pollution is due to agricultural run-off. Here mining industry is the second major pollutant. Sewage, industrial effluents and waste waters are **point source pollutants** while surface run off is a **nonpoint source pollutant**.

Differences Between Point and Nonpoint Sources of Water Pollution

<i>Point Source of Water Pollution</i>	<i>Nonpoint Source of Water Pollution</i>
<ol style="list-style-type: none"> 1. It is pollution caused by discharge of effluents at one point. 2. Due to large scale entry of pollutants at one point, the contamination and harmful effect on quality of water is maximum. 3. Treatment plant can be installed in the area of flow of effluents. 4. Other type of control measures are not required. 	<ol style="list-style-type: none"> 1. It is pollution caused by discharge of pollutants over a wide area. 2. There is some dilution of the effect of pollutants due to large size of area. 3. Treatment plant is useless for this type of pollution. 4. Control measures are required on a large scale for nonliberation of pollutants.

Domestic Sewage

It consists of everything that passes into sewer from residential areas, *i.e.*, human excreta, food residue, detergents, etc. Wastes from animal sheds, slaughter houses and food processing industries also carry similar contents. Only 0.1%, of municipal waste water (Fig. 16.4) consists of sewage impurities. The rest 99.9% is water. There are four types of impurities and dissolved solids.

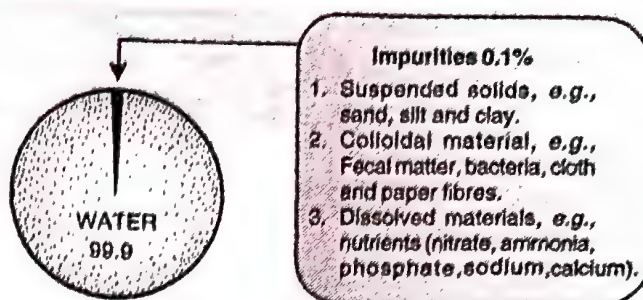


Fig. 16.4. Composition of municipal waste water.

(i) **Pathogens (Contaminants).** Raw sewage contains a number of pathogens (typhoid, dysentery, diarrhoea, cholera, giardiasis, amoebiasis, helminth eggs), coliforms and enterococci. Number of intestinal bacteria (*e.g.*, coliforms, enterococci) is an indication of pollution caused by raw sewage. Table 16.3. gives the degree of contamination of river Yamuna (=Jamuna) in Delhi, Agra and Mathura.

Table 16.2. Contamination Characteristics of River Yamuna

	Delhi	Mathura	Agra
Coliforms mpn/100 ml	10	84000	240000
Enterococci mpn/100 ml	21	46000	150000
BOD (mgm/litre)	2000	9000	12000

(ii) **Suspended Impurities.** They are suspended solids mostly made of sand, silt and clay. Most of the solids tend to settle if waste water is left undisturbed for sometime.

(iii) **Colloidal Particles.** They are both inorganic and organic components of sewage. The major inorganic colloid is clay. Organ colloids consist of faecal matter, bacteria and other microorganisms, cloth and paper fibres. Colloid particles form a near permanent colloidal solution. They can be removed only through decomposition of organic matter and addition of chemicals that cause flocculation or clumping of colloidal particles.

(iv) **Dissolved Solids.** Both inorganic and organic compounds form this fraction. Amongst the inorganic solids are nitrates, phosphates and toxic metal ions.

Biodegradation

Domestic sewage is rich in biodegradable organic matter. It stimulates the activity of several decomposer organisms collectively called **sewage fungus**. The property of becoming decomposed through microbial activity is known as **putrescibility**. Decomposition of organic matter by microbes requires oxygen. Degree of impurity of water due to organic matter is measured in terms of **B.O.D.** Biochemical oxygen demand or B.O.D. is the oxygen in milligrams required for five days in one litre of water at 20°C for the microorganisms to metabolise organic waste. Low pollution — below 1500 mg/L, medium pollution — 1500–4000 mg/L and high organic pollution — above 4000 mg/L. **COD** (Chemical Oxygen Demand) is the amount of oxygen required to oxidise all the reducing substances present in water. It includes BOD, reduced chemicals produced during putrefaction and other oxygen demanding chemicals. Oxygen used up in BOD or COD will reduce the amount of dissolved oxygen (DO). DO below 8.0 mg/L indicates pollution, below 4 mg/L heavy pollution.

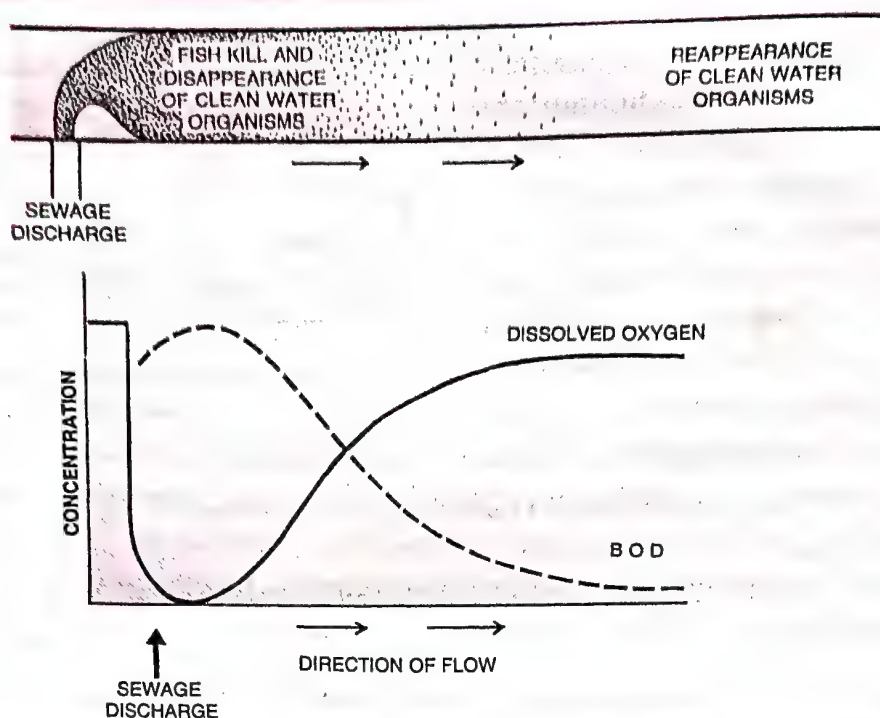


Fig. 16.5. Effect of sewage discharge in river and recovery of the same after some distance.

Discharge of domestic sewage into a river will result in rise of BOD because decomposer organisms consume a lot of oxygen. If sewage quantity is large, the whole of dissolved oxygen may be consumed leaving nothing for respiration of fish and other clean water organisms. They, therefore, get killed. However, as sewage is decomposed, there is a gradual rise in dissolved oxygen downstream. Fish and other clean water organisms reappear indicating the recovery of river from sewage pollution (Fig. 16.5).

Differences Between BOD and COD

BOD	COD
<ol style="list-style-type: none"> 1. It is oxygen required for microbial decomposition of a unit mass of organic remains. 2. It is comparatively lower. 3. Only aerobic decomposer microbes are involved. 	<ol style="list-style-type: none"> 1. It is oxygen required for chemical oxidation of a unit mass of reduced organic and inorganic materials. 2. It is comparatively higher. 3. Chemical oxidants are involved.

Eutrophication

It is excessive growth of algae, plants and animals in water bodies due to the nutrient enrichment particularly with nitrogen and phosphorus. Eutrophication is both **natural** and **accelerated**. Natural eutrophication is nutrient enrichment of a water body due to natural ageing. It is a slow process which may not be detectable in human life time. A young water body has cold, clear water where there is no nutrient enrichment. Run off and streams draining into it gradually add nutrients, especially nitrogen and phosphorus. This encourages growth of aquatic organisms. Organic debris and silt piles up at the bottom but more so near the periphery. Water becomes shallower and warmer. Warm water organisms appear. Marsh plants grow in shallow waters. Floating plants appear. Water body is gradually filled upon the shores and changed into land mass.

Cultural or accelerated eutrophication is nutrient enrichment of water bodies due to human activities like passage of sewage, industrial effluents and run off from fertilized fields rich in nitrates and phosphates. Nutrients present in sewage, agriculture wastes and fertilizers cause dense growth of plants and planktonic algae. They support a good number of animals. However, soon planktonic algae increase in number and impart a characteristic colouration to water depending upon the pigments present in them. The excess growth of planktonic algae that causes colouration of water is called **algal bloom**. In many cases blooms are formed by blue-green algae. They are toxic to animals and humans. In some cases eutrophic water bodies support excessive growth of floating plants. Water Hyacinth (*Eichhornia crassipes*) also called "Terror of Bengal" is one such plant that sometimes chokes ponds, lakes and rivers resulting in imbalance of ecosystem dynamics of water bodies. Algal blooms and floating plants cut off light from submerged plants. The latter die. There is drastic decrease in oxygen replenishment inside water. It causes organic loading of water. Decreased oxygen level also kills aquatic animals, further adding to organic loading. Decomposition is replaced by putrefaction which is anaerobic. It produces secondary pollutants that kill the bloom forming plants as well.

Colour and Odour. Organic loading produces brown colouration, foul smell and bad taste due to formation of secondary pollutants like methane (CH_4), ammonia (NH_3) and hydrogen sulphide (H_2S). Polluted water also becomes oily.

Scum and Sludge. Hydrogen sulphide (H_2S) reacts with various metallic ions to form sulphides. They produce scum and sludge alongwith organic matter.

Biota. Plankton, molluscs and fish will be eliminated due to reduced DO and presence of secondary pollutants. However, some pollution tolerant species survive, e.g., annelid worm *Tubifex* and some insect larvae like *Chironomus*. They are considered to be **pollution indicators**.

Sewage Treatment

Sewage pollution of water bodies can be prevented by treating sewage in **sewage or effluent treatment plant (ETP)**. There are three stages of treatment — primary, secondary and tertiary.

(a) **Primary Treatment.** It is also called **physical treatment**. The treatment consists of shredding, churning, screening and sedimentation. **Sequential filtration** removes both floating and large suspended solids. The filtrate is then passed into large **settling tanks**. Here grit, silt, small pebbles and other heavy articles settle down. In some treatments aluminium or iron sulphate is added to the filtrate to precipitate more solids. The sediment and the residue of sequential filtration constitute **primary sludge**. Primary sludge is used for biogas generation, composting and combustion.

The supernatant of the settling tank is called **effluent**. It is put to secondary treatment.

(b) **Secondary Treatment.** It is known as **biological treatment** as the step involves microbial decomposition of fine organic matter present in the effluent. The decomposing microbial flora is called **sewage fungus**. Two common secondary methods of secondary treatment are trickling filter method and activated sludge method. In **trickling filter method** treatment the effluent is allowed to drip through a thick bed of gravel having the sewage fungus. In the **activated sludge method** the effluent is taken to **aeration tanks** having some activated sludge of previous operation. The activated sludge has sewage fungus. Effluent is continuously aerated as well as agitated. Sewage fungus forms **flocs**. BOD decreases, as it decreases to 10-15% of original sewage, the waste water is taken to large **settling tank** where flocs

of sewage fungus settle down. The supernatant can be passed into water bodies. It can also be treated further.

The organic sediment is passed into **anaerobic sludge digester** where anaerobic microbes (generally methanogenic) decompose the organic matter as well as aerobic microbes. It is accompanied by liberation of biogas and formation of manure or compost.

(c) **Tertiary Treatment.** The cleared water is now **chlorinated** with chlorine or per-chlorate salts, ozonised or irradiated with UV to kill pathogens. It contains a lot of salts and other solids. Alum, ferric chloride and lime are used for their precipitation. They precipitate 90% of suspended solids and 90% of phosphates. Water can be passed into fields as manured water. It should be normalised and treated further with activated carbon for removal of dissolved organics and colouring agents (90%). Water is now treated for removal of salts (desalination) and nitrate. Ideally such a water should be recycled to irrigation. Another treatment for removal of DDT and other specialised compounds are required if water is to be passed on to reservoirs or used in industries (Fig. 16.6).

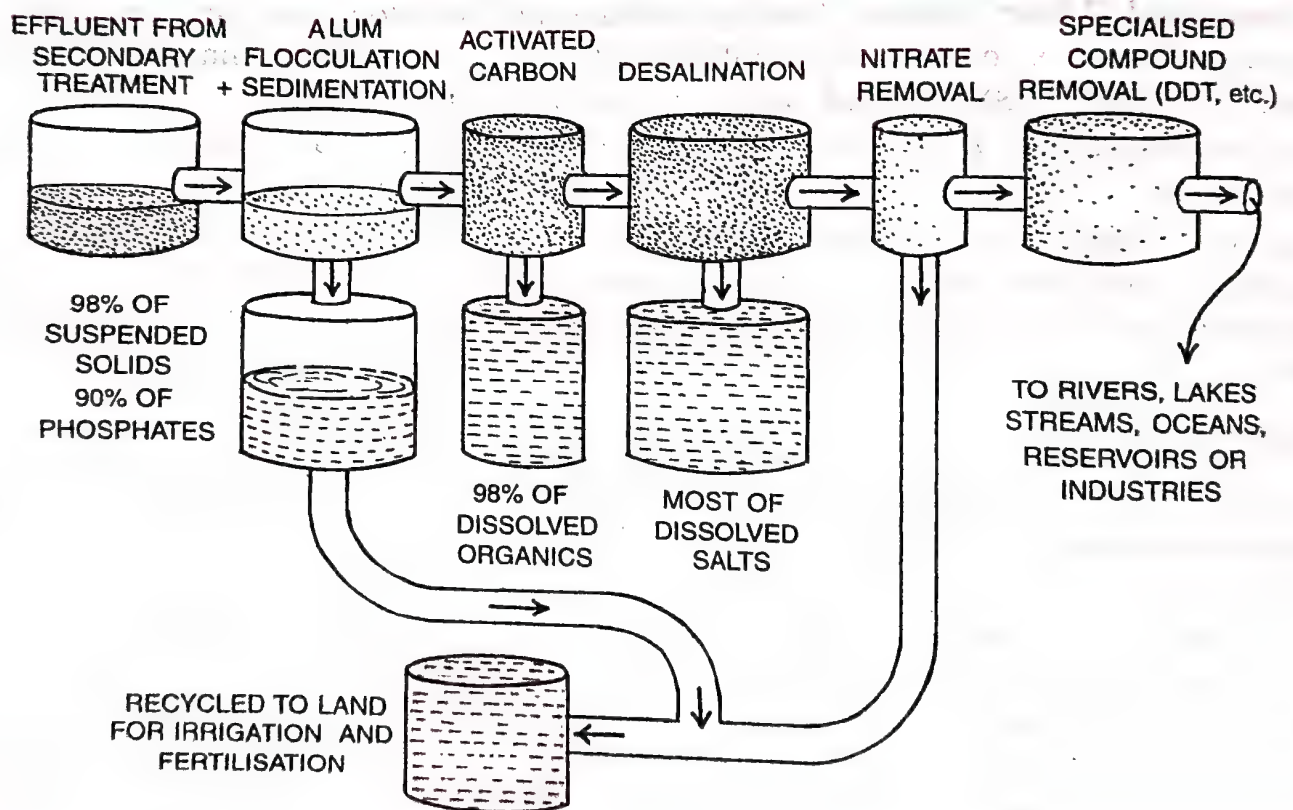


Fig. 16.6. Tertiary treatment of effluent treatment plant.

A Case Study of Integrated Waste Water Treatment

In the town of **Arcata** situated on Northern Coast of California an integrated waste water treatment process was developed with the help of biologists from Humboldt State University. It is a combination of artificial and natural processes. There are two stages (i) **Conventional method** of filtering, sedimentation and chlorine treatment for removing large organic re-dangerous pollutants (ii) **Innovative approach** consisted of developing a series of six connected marshes in 60 hectares of marshland seeded with bacteria, algae, fungi and plants.

The biota absorbs, assimilates and neutralises the pollutants. The naturally purified water is then allowed to flow out.

Alongwith functioning in water treatment, the marshes have been converted into a sanctuary where a number of fishes, other aquatic animals and birds have found residence. A citizen group called **friends of Arcata (FOAM)** looks after the project.

Ecosan Toilets

An ecologically compatible system of disposal of human excreta is the use of dry composting toilets, called **ecosan toilets**. No water is required. Human excreta is converted into a resource as it forms natural fertilizer. Ecosan toilets are already working in many parts of Kerala and Sri Lanka.

Thermal Pollution

Hot waste water is produced by many industrial, thermal power plants and oil refineries. It is drained out into water bodies. Consequently temperature of the water bodies rises. It decreases content of dissolved oxygen. Aerobic decomposition is replaced by anaerobic fermentation and putrefaction. Most organisms which are sensitive to high temperature get killed. Hot water is, however, useful in extremely cold areas, bringing life to aquatic systems but only after eliminating cold water flora and fauna.

Industrial Effluents

Waste waters from industries, paper manufacturing complexes, metal extraction and processing, petroleum refining, chemical manufacturing, etc. contain a number of harmful substances, both poisonous organic compounds and toxic heavy metals (elements with density of $>5\text{g/cm}^3$) like mercury, cadmium, copper, lead, etc.

(a) **Mercury.** It is changed to water soluble dimethyl mercury which undergoes biomagnification. Eating poisoned animals causes deformity known as **minamata (minimata) disease** (first reported in 1952 due to eating of fish captured from Hg-contaminated Minamata Bay of Japan) which is characterised by diarrhoea, hemolysis, impairment of various senses, numbness of lips, tongue, limbs, deafness, blurring of vision, mental dearrangement, meningitis and death.

(b) **Copper.** Hypertension, uremia, occasional fever and coma.

(c) **Lead** (also common from automobile exhausts). It interferes with haem synthesis, oxygen and glucose metabolism. Harmful effects include anaemia, vomiting, convulsions, loss of appetite, damage to liver, kidneys and brain.

(d) **Zinc.** Vomiting, cramps, renal damage.

(e) **Cobalt.** Diarrhoea, hypotension, bone defects and paralysis.

(f) **Chromium.** Gastro-intestinal ulcers, nephritis and nervous system disorders.

(g) **Cadmium.** Anaemia, hypertension, testicular atrophy, damage to liver and kidneys, cancer of liver and lungs, diarrhoea and painful skeletal deformities called **itai-itai** (ouch-ouch, first reported in 1947 in Toyoma city of Japan).

Industrial waste waters are toxic not only to humans but to all forms of life. It is, therefore, important that industrial waste water must be treated to remove polluting ingredients through various processes specified by pollution control board. Even the manufacturing process can be modified to prevent formation of harmful wastes. In case any industry fails to prevent pollution, the pollution control board is authorised to close down that industry.

Pesticides

Pesticides sprayed over crops also pass into water bodies due to surface run-off. In excess they cause immediate and mass scale deaths of aquatic animals.

Biomagnification

Heavy metals and persistent pesticides (e.g., organochlorine or chlorinated hydrocarbons like DDT) pass into food chain and increase in amount per unit weight of organisms with the rise in trophic level due to their accumulation in fat. The phenomenon is called **biomagnification/bioconcentration/biological amplification**, e.g., 0.003 parts per billion in water, 30 parts per billion or 0.003 ppm in phytoplankton, 0.04 ppm in zooplankton, 0.5 ppm in clams and small fish, 2.0 ppm in predator fish and 25 ppm in fish eating birds like Sea Gulls (Fig. 16.7). This was discovered when in an island of USA, regular DDT spray for a few years, resulted in drastic decline in the population of fish eating birds. There was 1000 times increase in concentration of DDT in phytoplankton as compared to water, 13 times in zooplankton as compared to phytoplankton, 9–40 times in different fish as compared to zooplankton and 25 times more DDT in fish eating birds as compared to fish. Higher amounts of pesticide disturb calcium metabolism of birds resulting in thinning of egg shells and their premature breaking that kills the embryos. Other disorders are cerebral haemorrhage, softening of brain, liver cirrhosis, hypertension and malfunctioning of sex hormones. Population of Bald Eagle had declined due to it. Consequently use of persistent pesticides has been banned in agriculture.

Recently microorganisms capable of metabolising chlorinated hydrocarbons have been discovered. They possess enzyme dehalogenase.

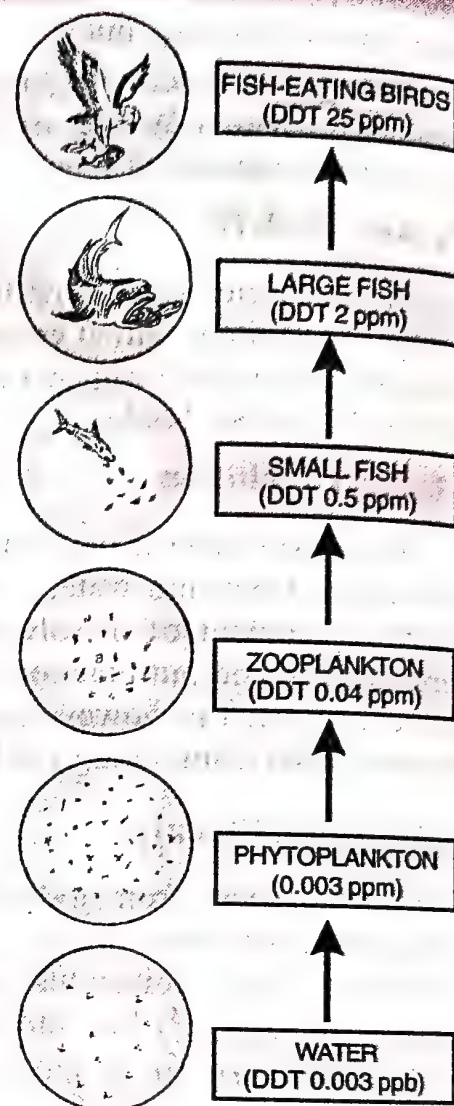


Fig. 16.7. Biological magnification of persistent pesticide like DDT in the tissues of organisms in an aquatic food chain.

Differences Between Biomagnification and Eutrophication

Biomagnification	Eutrophication
<ol style="list-style-type: none"> 1. It is entry and increase in concentration of nonbiodegradable substances in the food chains. 2. It is found in all types of ecosystems. 3. It does not result in organic loading. 4. There is no bloom formation. 5. It leads to toxicity in higher order consumers. 	<ol style="list-style-type: none"> 1. Eutrophication is enrichment of the water body with plant nutrients. 2. It is found only in aquatic ecosystem. 3. It leads to organic loading. 4. Bloom formation occurs in eutrophic waters. 5. It leads to death of most animals and plants.

Fertilizers

Part of fertilizers added to crop fields are passed down to water bodies during rains through surface run-off. Presence of extra nutrients brings about dense growth of plant and animal life. The phenomenon is called **eutrophication**.

Soil Pollution

It is alteration in soil caused by removal or addition of substances and factors which decreases its productivity, quality of plants and ground water. **Negative soil pollution** is reduction in soil productivity due to erosion and over-use. **Positive soil pollution** is reduction in soil productivity due to addition of undesirable substances (e.g., agrochemicals, industrial wastes, air pollutants washed down by rain, faulty sanitation). Pesticides and fertilisers are the two types of agrochemicals. **Landscape/third pollution** is converting fertile land into barren one by dumping wastes (e.g., ash, sludge, garbage, rubbish, industrial wastes, broken cans, bottles, etc.) over it.

1. **Pesticides**. They include insecticides, fungicides, algicides, rodenticides and weedicides. Pesticides are generally broad spectrum and function as **biocides**. Alongwith target organism they harm nontarget organisms as well. This destroys the ecosystem of the soil. (i) **Organochlorines/Chlorinated Hydrocarbons**. The important ones are DDT (dichloro diphenyl trichloroethane), BHC (benzene hexachloride), aldrin, dieldrin, endosulphan and endrin. They are **persistent**, fat soluble and show **biomagnification** whence they prove harmful to higher trophic level organisms. Hence, their use is being restricted. (ii) **Organo-Pesticides**. Degradable but toxic to workers, e.g., malathion, parathion, carbamates. (iii) **Inorganic Pesticides**. They contain arsenic and sulphur and are persistent. Hence, their use is highly restricted. (iv) **Weedicides**. They are often persistent and harmful.

2. **Fertilizers**. Excessive use of fertilizers causes soil deterioration through decrease of natural microflora. Leaching down of fertilizers causes pollution of underground water (third poison). Salts entering crop plants in excess may prove harmful. For example, nitrate rich leaves, fruits and water produce nitrite in alimentary canal that enters blood, combines with haemoglobin forming **met-haemoglobin** and reducing oxygen transport. It may prove fatal in infants. **Organic farming** involves use of biofertilisers, manures pesticides of organic origin, biological control and resistant varieties.

3. **Washing From Solid Wastes**. Solid wastes from municipalities and industries are often dumped temporarily over land. During rains heavy metals and toxic chemicals are washed down into soil and pollute the same.

Case Study of Organic Farming

Integrated organic farming is a cyclic zero waste procedure of farming where wastes of one process are cycled as nutrients for the next process. A farmer Ramesh Chander Dagar of Sonipat, Haryana, has developed one such system. He has integrated bee keeping, dairy management, water harvesting, composting and agriculture in a sustainable venture where different components support one another. Cattle dung is used as manure. Crop waste is composted. Both are also used to generate bio-gas and manure to meet the needs of the farm. Harvested water is used for irrigation. Farm provides sufficient fodder to cattle. Bees help in pollination of crop plants. Enthusiastic about success of his integrated organic farming, Dagar has set Haryana Kisan Welfare Club with a membership of some 5000 farmers.

Solid Wastes

Solid wastes are discarded or left over solid materials. The terms **rubbish** and **trash** are often used interchangeably for solid waste materials. The various sources of solid wastes are municipal wastes, industrial wastes, mining wastes, hazardous wastes, defunct ships and electronic wastes.

1. **Municipal Wastes.** They are solid wastes from homes, shops, offices, schools, hospitals, street and road sweepings which are collected and disposed off by municipalities. The major components are waste paper, textiles, leather, rubber metals, glass, plastic and polythene, food wastes, etc. A major ingredient of municipal waste is the packing material which is becoming bigger and more attractive to draw attention of customers. Even milk, water, fruits, vegetables and other edibles are being supplied in polythene, polystyrene and plastic covers. They are contributing heavily to environmental pollution.

2. **Industrial Wastes.** They include scrap, effluents, sludge and flyash. Flyash is fall out from industrial emissions especially thermal plants which is often mixed with smoke. It consists of oxides of silica, aluminium and iron alongwith small quantities of heavy metals.

3. **Mining Wastes.** They include mine dust, rock tailings, slack and slag. Open cast mining (surface dug out to bring out mineral deposit) completely spoils the surrounding soil. Toxic metals and chemicals present in the mining wastes destroys vegetation and produce many deformities in animals and human beings.

4. **Hazardous Wastes.** Industries producing pesticides, rubber, dyes, chemicals, paper and metals generate hazardous solid wastes. They are not only highly toxic to humans and other organisms but are also corrosive and highly inflammable. Hospital wastes are full of hazardous materials like infected organic wastes, pathogens, pathogen carriers, harmful chemicals, needles, syringes, vials, etc alongwith some disinfectants.

5. **Defunct Ships.** Old defunct ships are broken down in developing countries like India, Bangla Desh and Pakistan because of cheap labour and demand for scrap metal. These ships however, possess a number of toxic materials like asbestos, lead, mercury, tributyltin and polychlorinated biphenyls. The persons engaged in ship breaking are exposed to these toxic materials. The coastal areas where ship breaking is undertaken also become polluted.

6. **Electronic Wastes (E-Wastes).** They are irreparable computers, mobiles and other electronic goods often called e-wastes. Electronic wastes are generally sent to developing countries like India, China and Pakistan for extraction of metals like copper, iron, silicon, nickel and gold through recycling. However, this is done by hand which exposes the workers to toxic substances present in e-wastes. Waste electrical goods are similarly recycled but some of them like old batteries are quite hazardous to handle.

Developed countries enforced strict environmental laws in 1980s. This pushed up the cost of handling and treatment of hazardous wastes. They started exporting the wastes to developing countries. However, international protests produced an international treaty called Basel convention (after second largest city of Switzerland, Basel, where the treaty was signed). A scientific method of treating e-wastes in an environment friendly manner has been developed. It is called **evens**. The wastes are either shredded and buried deep in land fills or incinerated and the fumes detoxified.

Control of Solid Wastes

It involves collection and categorisation of wastes, transport to disposal site and disposal of waste. There are three categories of wastes – recyclable, biodegradable and nonbiodegradable

noncyclable. Disposal of wastes consists of (a) Recovery and Recycling, (b) Source reduction, (c) Burning, (d) Dumping.

1. **Recovery and Recycling.** It is carried out with the help of rag pickers. The articles which can be recovered and recycled are tins, cans and other metal wastes, glass, plastic, polyethylene, rags, paper and cardboard. Metal waste can be melted and purified. Broken glass is used similarly to form new glass. Waste paper and card board are recycled to form cardboard. Waste cotton textiles form paper. Plastic forms new but somewhat inferior plastic. Waste polyethylene is melted and recast to form new polyethylene.

Carry Bags. Because of their persistent nature and harmful effect on drainage system and stray animals, polybags are being banned by many governments, *e.g.*, H.P., Chandigarh. It is better that while going for shopping you take your own natural fibre carry bags.

2. **Source Reduction.** Garbage and other organic wastes are taken out of urban areas and used for formation of compost, biogas and manure. On smaller scale vermicompost is also practised.

(i) **Composting.** All types of organic wastes of a town are used to prepare a manure called compost. In composting the sludge obtained after primary treatment of sewage alongwith other wastes are allowed to decompose in an open space. In 4—6 months compost is ready for use as a manure. In some cases minerals are also added to the organic matter to enrich the compost.

(ii) **Gobar Gas Plants.** Cowdung and other organic wastes of farm houses can now be profitably placed in gobar gas plants which not only enrich manure but also provide gas for domestic use.

(iii) **Sludge Burning.** Where electricity is obtained from a thermal plant, sludge from sewage treatment can be mixed with coal to form fuel for power generation.

3. **Burning.** Burning is combustion of solid waste having organic waste in open places. It, however, produces offensive odours and air pollutants. Better methods are incineration and pyrolysis.

(i) **Incineration.** It is controlled aerobic combustion of wastes inside chambers at temperature of 900–1300°C. Incinerators are fitted with scrubbers and electrostatic precipitators to prevent release of smoke and toxic chemicals.

(ii) **Pyrolysis.** It is combustion inside chambers in the absence of oxygen at a temperature of 1650°C. It does not yield pollutants but industrial gas and other useful substances are produced.

4. **Construction Material.** Flyash is being converted into bricks for construction work. Flyash, industrial effluents containing toxic chemicals and hazardous metals can be used as bedding material for road construction.

5. **Dumping (Landfilling).** Damping is piling of waste on selected low lying land. It is of two types, open and sanitary.

(i) **Open Dumping (Open Landfill).** It is throwing of waste on uncovered low lying area. The waste is piled as high as the equipment can easily do. The waste is periodically burnt or compressed at intervals to reduce its bulk.

(ii) **Sanitary Dumping (Sanitary Landfill).** The waste is pulverised, compacted and covered over by a layer of earth.

Three Rs of Waste Management

The three Rs or rules of effective waste management are **reduce, reuse and recycle**. The first R relates to reduced generation of waste in all operations from mining to manufacture. The second R relates to reuse the article time and again like bottles and containers. The third R relates to recycling by collecting the waste and broken articles and manufacturing a new product, e.g., glass, plastic, metal articles.

Case Study Of Remedy For Plastic Waste

Ahmed Khan, a plastic sack manufacturer of Bengaluru since 1986, realised that plastic waste was a real problem and its recycling into sacks was no solution. In 1998, he developed **polyblend**, a fine powder of recycled modified plastic. In collaboration with RV college of Engineering and Bangalore City Corporation, he proved that the mixture of polyblend and bitumen was better for road carpeting as it had better water repellent property. It increased road life by a factor of three. By 2002, more than 40 km roads of Bengaluru were laid with the help of Khan's mixture. It has been 1400 km in 2012. Rag pickers who used to get ₹ 0.40 per kg of plastic waste are now getting ₹ 6.00 from Khan. Innovation like polyblend might protect the modern society from being smothered with plastic waste.

Radioactive Wastes

They are wastes which release radioactivity (emission of α -particles, β -particles or gamma rays) from **nuclides** of their elements. Traces of radioactive elements occur in a number of products, e.g., polonium in tobacco, radon indoors, several ores. Depending upon the amount of radioactivity, there are three types of radioactive wastes — low level, intermediate level and high level.

Low Level Radiation. (i) Extremely small amount of radioactivity enters coolant water used in atomic reactors and ponds used for quenching heat and radioactivity of spent fuel. It undergoes biomagnification to some 75,000 times in birds. (ii) Radioactive wastes are produced by testing laboratories, irradiation centres for induction of mutations, study of metabolic pathways, radiotherapy and other centres using radioisotopes.

Intermediate Level Radiation. It is radiation which is not accompanied by liberation of much heat. There is not much problem in disposal of wastes emitting intermediate level radiations. Small amounts of these radioactive wastes occur in all ores. They are separated during refinement. If not dumped properly, the radioactive wastes can kill vegetation and cause irreparable injuries to humans and animals.

High Level Radiations. They are highly destructive radiations which develop due to (i) Accidental leakage or meltdown of atomic reactors, e.g., Three Mile Island, Chernobyl. (ii) Spent fuel of atomic reactors. High level wastes produce a lot of heat and large amount of radiations. Even short duration exposure to such high level radiations causes loss of hair and nails, subcutaneous bleeding and damage to all organs. The radiations cause tumours, cancers and genetic deformities.

High level wastes require special protective shields during handling and transport. They need cooling. The wastes are first concentrated to reduce their bulk, kept in thick leak-proof containers and dumped for 50-100 years in small ponds in the premises of nuclear plants. Their storage dissipates major part of both heat and radioactivity. The weakened radioactive wastes kept in shielded containers is then buried 500m down deep inside earth. Sea bottom is also used for it. However, environmentalists are opposing both the methods of disposal.

Noise Pollution

It is a physical form of pollution that affects the receiver directly. Noise pollution is loud disturbing sound dumped into ambient atmosphere without caring for the adverse effect it may have. Noise or pollutant sound has a value of 80 dB and above. Frequency of sound is measured in Hz (Hertz). Range of human hearing is 50 Hz to 15000 Hz. **Infrasonic** vibrations (below 50 Hz) can be felt because some body parts resonate at this frequency. **Ultrasonic** vibrations (above 15000 Hz) are used in imaging, cleaning, drilling, cutting, welding and sealing. Intensity of sound is the rate at which energy from the wave is transferred on to the surface per unit area or W/m^2 . **Sound level** is logarithm of ratio of ambient intensity to reference intensity (e.g., 10^{-12} W/m^2). **Unit of sound level** is **decibel** (dB, after Graham Bell). At reference intensity, sound or noise level is taken as 0.0 dB. 10 dB is ten times the threshold intensity, 20 dB 100 times, 40 dB, 10^4 , 100 dB 10^{10} times the threshold intensity. Moderate conversation produces 60 dB sound, loud conversation 70 dB, scooter 80 dB, plying of truck/bus 90 dB, jet aeroplane 150 dB, rocket 180 dB. Unwanted sound is **noise** and is, therefore, pollutant. A regular exposure to sound of 80 dB (day time noise level in metropolitan cities) reduces hearing by 15 dB in ten years. Noise becomes uncomfortable above 100 dB.

Sources of Noise Pollution

Main sources of noise pollution are :

- (i) Various industries such as textile mills, printing presses, engineering establishments.
- (ii) Agricultural machines like tractors, harvesters, tubewells etc.
- (iii) Defence equipment such as tanks, artillery, rocket launching, shooting practices, explosions.
- (iv) Entertaining equipment like radios, record players, television sets.
- (v) Domestic gadgets such as desert coolers, air conditioners, vacuum cleaners, exhaust fans, mixers, pressure cooker.
- (vi) Public address systems like loud speakers.
- (vii) Transport vehicles like scooters, motor-cycles, car, buses, trucks, trains, jet planes.
- (viii) Dynamite blasting.
- (ix) Crackers used at occasions like marriages and festivals.
- (x) Bull dozing, stone crushing, construction work, etc.

Effects of Noise Pollution. Noise pollution causes psychological and physiological disorders in humans. It affects both hearing and general health of man.

(1) **Effect on Hearing.** (a) A sudden loud noise of 150 dB or more may permanently damage ear drum or dislocate ear ossicles. Such a sound level occurs at the time of take off of a jet, rocket or bomb explosion. (b) A prolonged exposure of even low level noise (80–100 dB) as found in many industries and metropolitan cities near the roads may permanently damage hearing ability of humans. (c) Noisy surroundings in the cities reduce the ability to listen to soft voices and whispers.

(2) Effects on General Health

(a) The first effects of noise are anxiety and stress. However, in extreme cases it may lead to fright.

(b) Noise causes headache by dilating blood vessels of the brain, eye strain by dilating

the pupil, digestive spasms through anxiety and high blood pressure by increasing cholesterol level in the blood.

(c) Noise pollution also causes increase in the rate of heart beat, constriction of blood vessels, decreased heart output, and defective night and colour vision.

(d) Noise may cause altered breathing pattern resulting in stress.

(e) It may cause insomnia or sleeplessness.

(f) A sudden high intensity of sound produces a startle reaction which may affect psychomotor performance.

(g) Noise also causes emotional disturbances.

(h) Noise can impair the development of nervous system of unborn babies which leads to abnormal behaviour in later life.

(i) It has been reported that prolonged noise pollution causes damage to heart, brain and liver.

Effect of Noise on Animals

Noise pollution produces a number of adverse effects on animals. (i) Ability to listen to stealth movement of enemies is lost. (ii) Functioning of many internal organs including endocrine glands is disturbed. (iii) Reproductive cycles of several insects is disturbed. (iv) Egg laying of birds is disturbed. (v) Development of embryo is affected. Congenital defects appear in foetus or embryo of not only animals but also of humans. (vi) Hatching of birds is disturbed.

Control of Noise Pollution

1. **Decibel Meters.** They should be installed at different places in order to monitor the level of noise pollution.

2. **Noise Pollution Control Laws.** The laws should be strictly enforced. Ambient noise levels should be followed.

	Day	Night
Industrial Zone	75dB	70 dB
Commercial Zone	65 dB	55 dB
Residential Zone	55 dB	45 dB
Silence Zone	50 dB	40 dB

3. **Acoustic Zoning.** Populated area is divided into four zones—silence zone (near hospitals, educational institutions), residential zone, commercial zone and industrial zone. Silence zones are also called **horn free zones** as use of horns is not allowed.

4. **Machines.** All machines whether industrial or engines of motor vehicles should be designed to produce lesser noise, maintained properly and lubricated from time to time.

5. **Loudspeakers and Entertainment Gadgets.** The volume should be kept low. Loudspeakers should not be used beyond the permissible time.

6. **Crackers.** There is a permissible sound level and timing for use of crackers during festivities and other ceremonies.

7. **Sound Diversion.** Devices are available to deflect the sound.

8. **Buildings.** (i) They should have a proper layout for reducing the intensity of sound coming from road side, commercial or industrial complex. (ii) Growing and maintaining green belt of trees and shrubs around the residential area as well as along rows of houses. (iii) Covering of outer surface of buildings with sound absorbers like acoustic tiles and rough cement coating. (iv) Use of rubber-plastic foams in ceilings and floors. (v) Acoustic furnishings inside the buildings.

9. **Green Muffler or Green Belt Vegetation.** Green muffler or green belt vegetation is rows of trees and shrubs grown and maintained to serve as noise absorbers. It also reduces air pollution because the trees and shrubs absorb pollution gases and cause settling of suspended particulate matter. Green muffler or green belt vegetation is specially planted along roads, and rails for absorption of noise, pollutant gases and dust generated by moving vehicles. It is grown around industrial complexes in the form of wider belts for insulating the residential and commercial complexes not only from sound, smoke, dust, pollutant gases but also accidental release of toxic gases. Green belt of trees and hedges around domestic units is meant for protecting residential areas from outside noise and air pollution as well as similar pollution generated by individual dwelling units.

10. **Ear Plugs and Ear Muffs.** Traffic police personnel and factory workers exposed to high noise pollution should be provided with ear plugs or ear muffs. (i) **Ear Plugs.** They are devices which fit into ear canals for blocking or attenuating sound waves. Ear plugs are of two types, permanent and disposable. They are made of glass down (very fine glass-wool) or cotton wool impregnated with wax. (ii) **Ear Muffs.** Ear muffs are hard shells that are attached to head and cover the external ears completely in order to block sound waves entering the ears. Ear muffs contain fluids seals or plastic foam for absorbing sound. Individual fitting into ear canals is not required.

Environmental Laws For Controlling Pollution

1. **Environment (Protection) Act, 1986.** It is the most comprehensive law meant for prevention, control and abatement of environmental pollution by laying down emission norms and setting up of central and state pollution control boards. The boards check the emissions and effluents by various institutes and industries, their treatment and disposal. The act encompasses pollution limits of air, water, soil and noise. Rules have been framed under this law from time to time such as (i) Hazardous Wastes (Management and Handling) Rules, 1989. (ii) Noise Pollution (Regulation of Control) Rules, 2000. (iii) Biomedical Waste (Management and Handling) Rules, 1998. (iv) Recycled Plastic Manufacture and Usage Rules, 1999. (v) Ozone Depleting Substances (Regulation and Control) Rules 2000. (vi) Municipal Solid Wastes (management and Handling) Rules, 2000.

2. **Insecticide Act, 1968.** It regulates manufacture, import, sale, transport, distribution and use of insecticides, laying down various rules to reduce risk to human health and health of other organisms.

3. **Water (Prevention and Control of Pollution) Act, 1974.** It specifies quality of water for various purposes, ways and means to control water pollution and prevention of detrimental effects on human health and health of other biological entities.

4. **Air (Prevention and Control of Pollution) Act, 1981.** The act is meant for preserving quality of air, controlling air pollution and preventing detrimental effects of air pollutants and human health and health of other biological entities. By an amendment in 1987, noise was also recognised as an air pollutant.

Global Environmental Changes

Human population has been growing rapidly. It has crossed 6 billion mark in 1999. Per capita consumption of resources has increased to many times (e.g., 25 litres of fresh water to 250 litres/day). This has strained in life supporting system of earth and brought about a number of environmental changes on the global scale. (i) Forest cover of the world was 50% of land area in 1900, 40% of land in 1950s and less than 30% in 2000. It has resulted in increased desertification, irregular rainfall, more floods, increased soil erosion, loss of perennial flow in rivers, reduced ground water and, therefore, increased drought. (ii) More and more people are migrating to towns and cities. There is rise in the number of slums and consequent increase in filth and pollution. (iii) Increase in quantity of solid wastes. (iv) Rise in industrial wastes and pollutants. (v) Increased passage of pesticides and fertilizers in water bodies and food chains. (vi) High rate of consumption of fossil fuels is adding CO_2 , SO_2 and a number of other gases and chemicals into the atmosphere causing acid rain, ozone depletion, global warming and frequent foggy weather.

Green House Effect (Fourier, 1827 ; Arrhenius)

It is warming effect found in green house by allowing solar radiations to pass in but preventing long wave heat radiations to pass out due to glass panes, water vapours and carbon dioxide. Because of it green houses are used for growing tropical plants in temperate areas. Green house warm up is similar to the inside of a car parked in the sun for an hour or so. Dusty/humid/cloudy nights are warmer due to it.

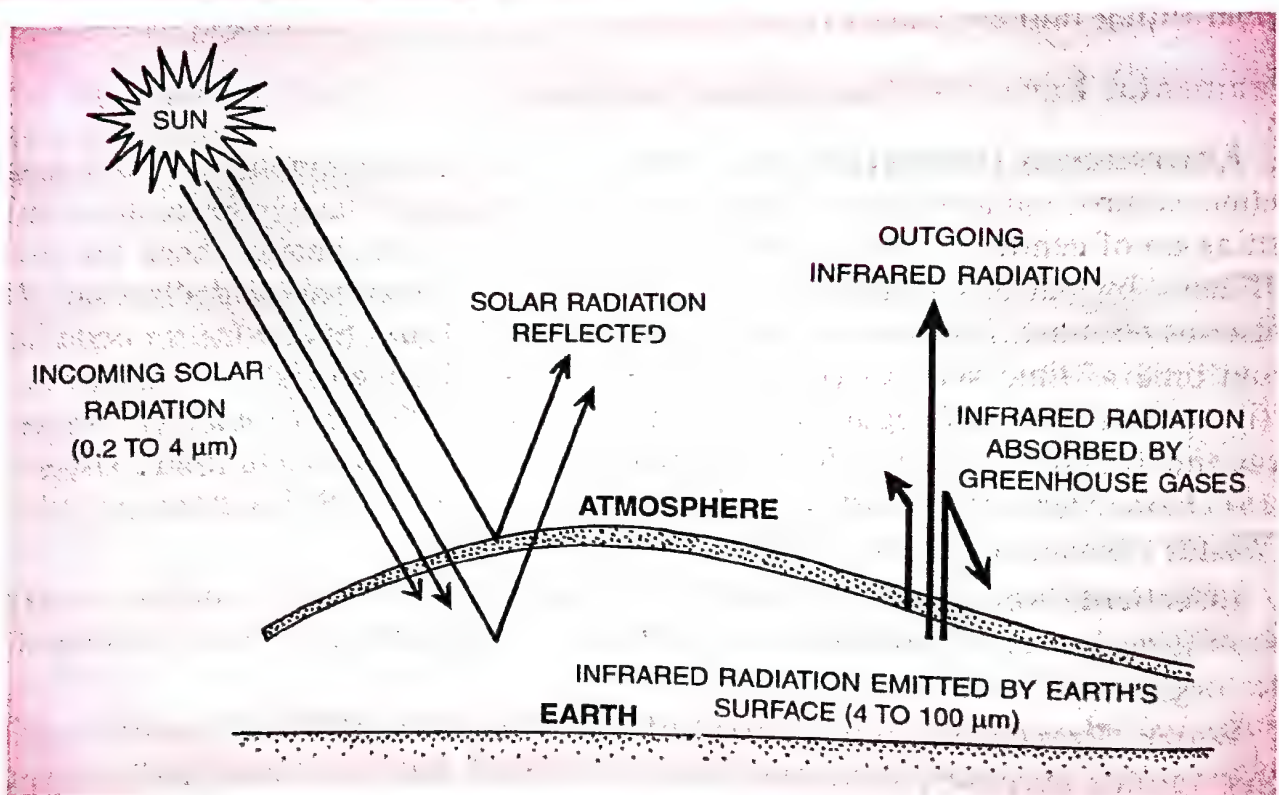


Fig. 16.8. Greenhouse effect in keeping the earth warm.

The whole of sunlight does not reach the earth. About one fourth of incoming solar radiations are reflected back by clouds and gases. Another one fourth of radiations are absorbed by atmospheric gases. Only 50% of solar radiations reach the earth and heat it up.

A small proportion is reflected from earth's surface. Heat of the surface of earth is emitted in the form of infra-red radiations. Only a tiny fraction goes into space. The remaining are absorbed by atmospheric gases and reflected back to earth to keep it warm. From earth long wave radiations pass into atmosphere. However, a major part comes back to earth to go back to atmosphere again. The cycle continues till earth surface has no long wave radiations to limit.

The gases which are transparent to solar radiation but retain and partially reflect back long wave heat radiations are called **green house gases (GHGs)**. Green house gases are essential for keeping the earth warm and hospitable (Fig. 16.8). They are also called **radiatively active gases**. They prevent a substantial part of long wave radiations emitted by earth to escape into space. Rather green house gases radiate a part of this energy back to the earth. The phenomenon is called **green house flux**. Because of green house flux, the mean annual temperature of earth is 15°C . In its absence it will fall to -18°C . However, recently the concentration of green house gases has started rising resulting in **enhanced green house effect** that is increasing the mean global temperature. It is called **global warming**. A regular assessment of abundance of green house gases and their impact on global environment is being made by IPCC (Intergovernmental Panel on Climate Change). The various green house gases are CO_2 (warming effect 60%), CH_4 (effect 20%), chlorofluorocarbons or CFCs (14%) and nitrous oxide (N_2O , 6%). Others of minor significance are water vapours and ozone.

1. **Carbon Dioxide.** Its atmospheric concentration was 280 ppm in 1750, 368 ppm in 2000, 380 ppm in 2007 and 400 ppm in 2013. The rise has been due to large scale deforestation (for grazing land, cropland or urban estates), change in land use and large scale combustion of fossil fuels. Nearly 33% of Indian land was covered by forests in the beginning of 20th century. It was reduced to 19.4% by the end of this century. 90% of Europe was covered by forests in the mediaeval era. It is 20% at present. Deforestation has reduced carbon dioxide assimilation. The excess remains in the air. Excessive use of fossil fuel is adding more CO_2 to atmosphere. In 1987 some 14,600 million tonnes of CO_2 was produced by earth. Only 63% of it was used in photosynthesis and absorption by water bodies. The remaining 5900 million tonnes of CO_2 passed into atmosphere and increased its concentration.

2. **Methane.** Its concentration was 700 ppb in pre-industrial times and 1750 ppb in 2000. Methane is produced by incomplete biomass combustion, incomplete decomposition mostly by anaerobic methanogens. Flooded paddy fields, marshes, cattle (enteric fermentation) are the major sources of this gas. In arctic regions, methane is coming out of earth's interior at many places called **methane chimneys**.

3. **Chlorofluorocarbons (CFCs).** They are synthetic gaseous compounds of carbon and halogen which are odourless, non-toxic, noninflammable, chemically inert propellants used in aerosol cans and jet fuel, refrigerants in air conditioners and refrigerators, production of industrial solvents, fire extinguishers and plastic foams. Chlorofluorocarbons have been

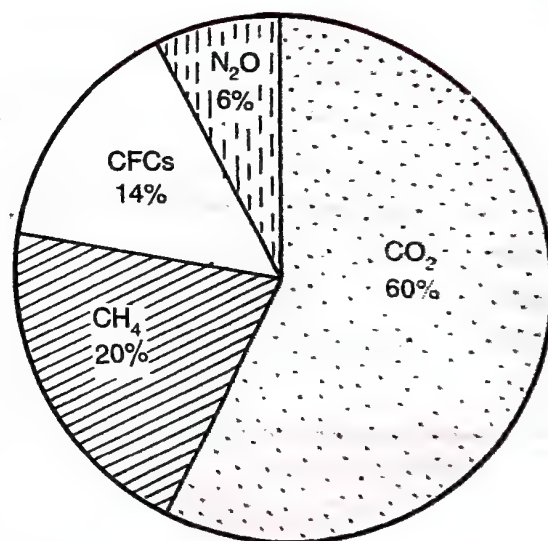


Fig. 16.9. Contribution of different gases to green house effect.

synthesised in 20th century but due to their widespread use and long atmospheric residence (45–260 yrs), their concentration in atmosphere steadily rose to reach 282 ppt. There are two categories of fluorocarbons, CFC-11 and HFC-23. Due to effect of Montreal Protocol, CFCs concentration has been slowly declining since 2002.

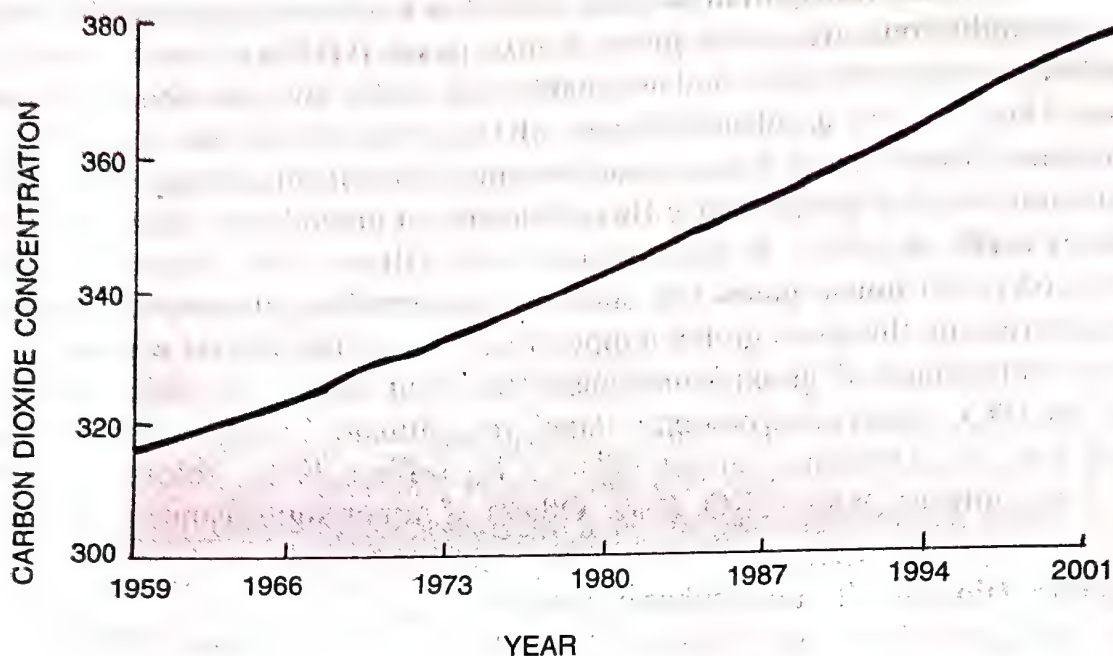


Fig. 16.10. Mean rise in CO₂ concentration in atmosphere between 1959 and 2001.

4. **Nitrous Oxide (N₂O).** Its atmospheric concentration was 270 ppb in pre-industrial times. The present day concentration is 316 ppb (324 ppb in 2015). It is produced by combustion of nitrogen rich fuels, livestock wastes, breakdown of nitrogen fertilisers in soil, nitrate contaminated water, nylon production and some other industrial processes.

Increase in Concentration of Greenhouse Gases

Greenhouse Gas	Pre-industrial Concentration	Concentration in 2000 AD	Increase since 1750 AD, %	Atmospheric life time (yrs)
1. Carbon dioxide (CO ₂)	280 ppm	368 ppm	31	5–200
2. Methane (CH ₄)	700 ppb	1750 ppb	151	12
3. Nitrous oxide (N ₂ O)	270 ppb	316 ppb	17	114
4. Chlorofluorocarbons (CFC-11) Hydrofluorocarbons (HFC-23)	0	282 ppt.	—	45 – 260

Effects. (i) CO₂ Fertilisation. Manna Loa Observatory of USA has recorded an increase in CO₂ concentration from 316 ppm in 1959 to about 374 ppm in 2001. If the trend continues, CO₂ concentration can go upto anywhere between 540–970 ppm by the end of 21st century. Increase in CO₂ concentration increases the rate of photosynthesis especially in C₃ plants. Amount of stomatal conductance will decrease resulting in lower rate of transpiration. There will be greater root growth, more mycorrhizal development and increase

in N_2 fixation in root nodules so that plants will grow more successfully in regions of water scarcity and nutrient poor soils. However, these beneficial effect will be nullified by negative effects of global warming.

(ii) **Global Warming.** It is believed that increase in concentration of green house gases has resulted in rise of atmospheric temperature, some 2.5°C since industrial revolution and 0.6°C in the twentieth century, mostly during its last three decades. Rise in atmospheric temperature has been confirmed by IPCC (Intergovernmental Panel on Climatic Change, 1991, 1992). By the year 2100 average temperature of earth would rise by $1.4^\circ - 5.8^\circ\text{C}$ over 1990 level. Rise in temperature will be slight in tropics, moderate in middle latitudes and maximum in polar regions (World Climate Programme, WCP, 1988). There will be melting of polar ice caps and mountain snow caps (e.g., Himalayan snow caps). Alaska Permafrost has recorded a rise in $2^\circ - 4^\circ\text{C}$. Ice-free season has also increased by 3 weeks. The effects of global warming are :

(a) **Effect on Atmosphere.** Warming of troposphere is accompanied by cooling of the upper strata of atmosphere. Upper atmosphere has shrunk by 8 km. Cooling in the stratosphere will tend to increase the size of ozone holes while cooling in thermosphere will disrupt radio communications and further warm the troposphere.

(b) **Effect on Weather and Climate.** Odd climate changes like EL Nino effect would become common. Moisture carrying capacity of air will increase. Pattern of air-mass movement will change. Precipitation will increase at higher latitudes both in summer and winter and in southern as well as eastern Asia in summer. Winter precipitation will be reduced at lower latitude. Frequency of droughts and floods will increase. Threat to human health will increase in tropical and subtropical countries due to changed ranges of disease vectors and water borne pathogens.

(c) **Changes in Sea Level.** Rise in temperature will raise sea level due to thermal expansion of sea water, melting of glaciers and Greenland ice sheet. NASA has found that between 1993–1998, Greenland ice has melted between 20–100 cm. Sea level has risen by 15 cm during the twentieth century, a rise of 1–2 mm per year. By 2100 yr, sea level may rise by 0.88 m over 1990 level. There is a danger of submersion of large area as one third of human population lives within 60 km of coast line. The whole of Maldives, several thousands of other islands, 11.5% of Bangladesh and several important cities of the world will be submerged. Coastal salt marshes and estuaries, wetlands, drylands, fresh water supplies, fisheries, fish breeding areas and other types of wildlife will undergo extinction.

(d) **Effects on Range of Species.** Rise in temperature of $2-5^\circ\text{C}$ will push temperate range by some 250–600 km pole-wards. Many tree species and others which are sensitive to temperature will die out resulting in conversion of forests into scrub vegetation. A similar change will occur in altitudinal zonation.

(e) **Food Production.** Rise in temperature is detrimental to crop productivity due to increase in respiration, greater growth of weeds, eruption of diseases and pests, especially in tropical and subtropical areas. Rice yield is likely to decrease by 5% in south-east Asia for every 1°C rise in temperature. Small temperature rise may increase crop productivity in temperate areas but higher temperature rise will be detrimental. Therefore, despite increase in CO_2 fertilisation, the overall crop productivity will be reduced.

Strategies to Deal with Global Warming. (i) Complete replacement of chlorofluorocarbons with substitutes that have little effect on ozone and global warming. (ii) Increasing vegetation cover/forests for photosynthetic utilisation of CO_2 . (iii) Reduction in use of nitrogen fertilisers and instead relying more on nitrogen fixation. (iv) Limiting use of fossil

fuels by developing alternate sources of energy, e.g., solar energy, wind energy. (v) Improving efficiency of energy usage. (vi) Checking population growth.

Warming Pause. Since 2002, earth has stopped warming up further. Rather, it may be heading for cooling. Scientists are currently unable to find the exact cause — may be rise in ozone concentration, weakening of El Nino, ocean effect or consumption of energy in melting of ice sheets and caps.

Ozone Depletion

Ozone layer or shield is present in the stratosphere. It is also called **ozonosphere**. Ozonosphere lies at altitude of 23–25 km over equator and at slightly lower altitude elsewhere with 11–16 km height over poles. 90% of atmospheric ozone is present in ozonosphere. Thickness of ozone is measured in **Dobson units (D.U.)**. Concentration of ozone in the ozonosphere is above 0.3 ppm or 300 dobsons as compared to 0.05 ppm (50 dobsons) in troposphere. The total thickness of ozone if condensed is 0.29 cm above equator and 0.40 cm above poles towards the end of winter. In stratosphere ozone is being formed and photodissociated. It dissipates the energy of UV radiations.

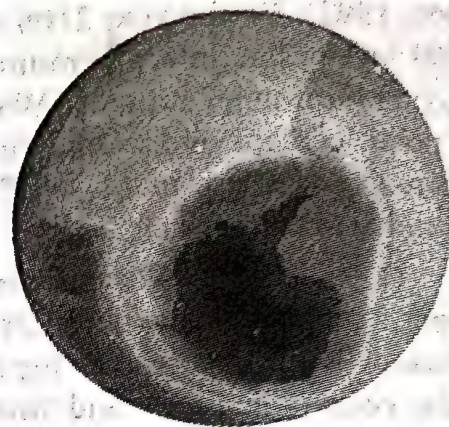
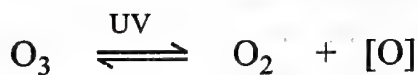


Fig. 16.11. Ozone hole.



Because of its ozonosphere functions as shield against strong UV radiations. Protection from UV radiations is proportional to thickness of ozone layer. More UV radiations reach the earth over the tropics. The amount decreases towards the poles. However, thickness of ozone over the poles changes with the seasons being lowest in polar spring (antarctic spring = autumn in northern hemisphere) and maximum in polar autumn (antarctic autumn = spring in northern hemisphere).

Ozone Hole. Depletion in the concentration of ozone over a restricted area as over antarctica is called **ozone hole**. During 1956–1970 period, springtime thickness of ozone over antarctica was 280–325 dobson units (DU = 1 ppb). During 1979 it was 225 DU, 136 DU in 1985 and 94 DU in 1994. Fortunately a 15% decrease in ozone hole as compared to late 1990s has been recorded in 2011 (Salby *et al* 2011). It has risen again in 2015. Springtime depletion of ozone is due to action of sunlight over pollutants which release chemicals (e.g., chlorine) that destroy ozone. An ozone hole was discovered over Antarctica by Farman *et al*, 1985 who also coined the term. It is quite large (23 million square km in 1992 and 28.3 million sq. km in 2000). A small ozone hole also occurs over North Pole. It was discovered in 1990. Thinning of ozone shield has also been reported elsewhere (e.g., 8% between 30° – 50°N), e.g., over Tibet and Hindukush. In the period in between 1997–2001 the global average ozone column has declined by 3% below pre-1980 level. Thinning of ozone shield will increase the amount of UV-B radiation reaching the earth, 2% more in case of 1% loss of ozone, 10% more in case of 5% depletion of ozone. The latter will result in 2,50,000 more persons catching skin cancer and 5,00,000 more persons becoming blind.

ODS. They are substances which react with ozone present in the stratosphere and destroy the same. The major ODS are chlorofluorocarbons (14% of total depletion), nitrogen oxides (3.5% depletion), sulphur dioxide, halon, carbon tetrachloride, methyl chlorofom,

chlorine, etc. Many of these are being released by jets flying in the stratosphere and rockets being fired into space. Others are persistent in the troposphere and gradually pass into stratosphere. Maximum ozone depleting potential or ODP is of chlorofluorocarbon due to release of **active chlorine** (Cl , ClO) by it. Active chlorine gets perched over atmospheric ice crystals and remains functional for a long time. A single chlorine atom converts 1 lakh molecules of ozone into oxygen. The reactions were discovered by Molina and Rowland (1974, Nobel Prize, 1995 alongwith Crutzen). Chlorine action over ozone is chainamictic.

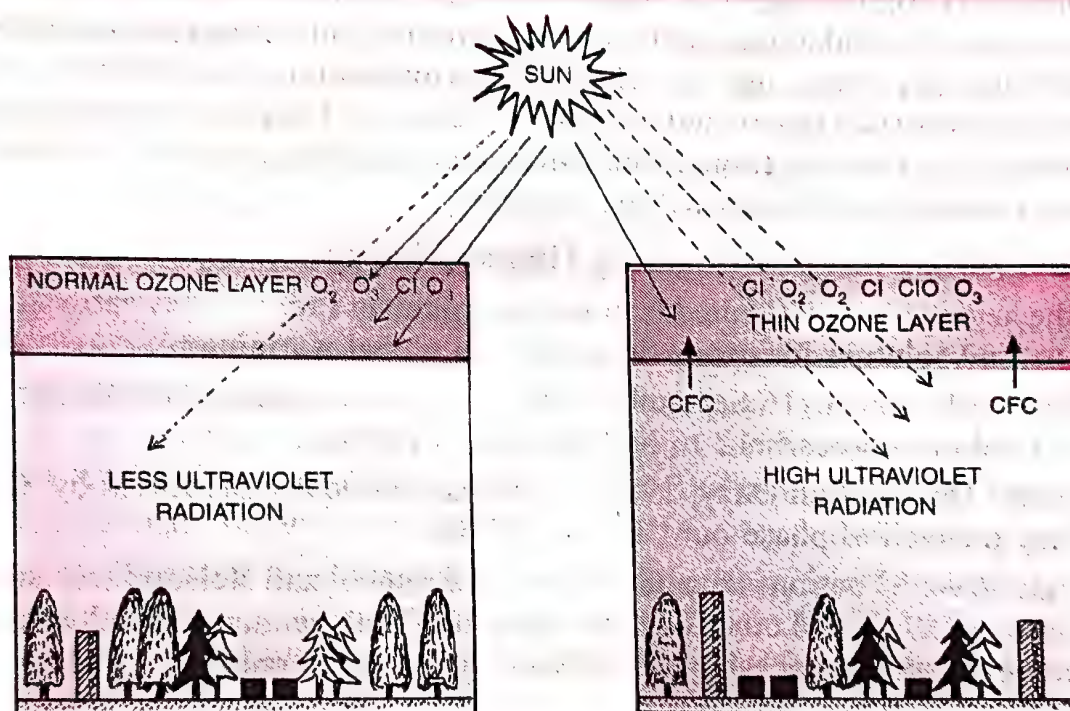
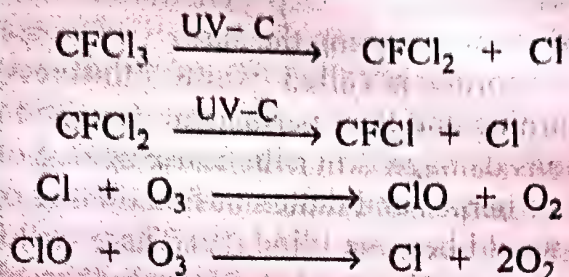


Fig. 16.12. Effect of ODS on ozone layer.

Consequently, chlorofluorocarbons (CFCs) are being replaced by hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs). Carbon tetrachloride, halon and methyl chloroform also deplete ozone by a similar method. Nitric oxide (NO) and other gases released by jets directly react with ozone to form oxygen.



Ozone Hole Over Antarctica

Every year ozone hole is formed over Antarctica during spring of Southern Hemisphere (September – October). Ozone depleting substances (e.g., CFCs) released by industrialised countries of Europe, North America, Russia and Japan reach stratosphere from where they are pushed towards poles by winds. During winter there is no sunlight. The temperature is very low (-85°C). It favours formation of **ice clouds**. At this time Antarctic air is completely isolated from the rest over the earth. It circulates over the polar region and is called **polar**

vertex. Ice clouds provide catalytic surface where chlorine and other reactants of ODS can react with ozone and degrade it. However, sunlight is necessary for it. It is available during spring, when ozone depletion occurs on a large scale. Ozone hole disappears during summer as warmth mixes up antarctic air with air of other parts of the world.

Effects of Ozone Depletion. Ultraviolet radiations are of three types — UV-C (100–280 nm), UV-B (280–320 nm) and UV-A (320–390 nm). Shorter ultraviolet radiations (UV-C) are absorbed by the atmosphere. The longer ones are not much harmful. The intermediate or UV-B are harmful as well as capable of deep penetration. Thinning of ozone layer increases the amount of UV-B radiations reaching the earth. (i) Cornea absorbs UV-B radiations. It becomes inflamed. The disorder is called “**snow blindness**” cataract. It leads to diminishing of eye sight, photoburning and later permanent damage to cornea that results in actual cataract. (ii) UV-B radiations damage skin cells cause ageing of skin and skin cancer. (iii) There is increased incidence of herpes and deficient functioning of immune system. (iv) A large number of land animals would become blind. (v) There will be higher mortality of young ones of animals. (vi) Damage to nucleic acids will increase resulting in higher number of mutations. (vii) High energy UV radiations break chemical bonds of proteins and other biomolecules. (viii) UV radiations inhibit photosynthesis by affecting photosynthetic machinery. Productivity of oceans, due to affect on phytoplankton will decrease by 6–22%. Productivity of terrestrial systems will fall by 10–25%. (ix) Decreased photosynthetic activity will increase CO₂ concentration of the atmosphere resulting in global warming. (x) Both marine and terrestrial food chains will be disturbed.

International Initiative For Mitigating Global Change

Under the aegis of UNEP (United Nations Environment Programme) various efforts have been made to find solution for ozone depletion and global warming.

1. **Montreal Protocol** (16 September 1987). 27 industrialised countries agreed to limit production of chlorofluorocarbons to half the level of 1986.

2. **Helsinki Declaration** (May, 1989). Montreal Protocol was ratified by 82 nations at Helsinki. They pledged to phase out CFCs by 2000.

3. In June 1990, 93 nations amended Montreal Protocol and Helsinki Declaration. They agreed to phase out CFCs and other ODS by the end of 20th century. A fund was established to help developing nations in phasing out ODS and adopting alternatives. Till date 175 nations have signed it.

4. **Intergovernmental Panel on Climate Changes (IPCC, 1988)**. Prepared a world climatic programme (WCP).

5. **Convention on Climate Change (CCC)**. Under UN framework in 1991.

6. **Earth Summit** (United Nations Conference on Environment and Development, 1992). It was held in Rio-de-Janeiro (Brazil) and adopted the recommendations of CCC for reducing greenhouse gases. The recommendations were signed by 154 nations. They pledged to maintain emission of green house gases at 1990 level. United Nations Framework Convention on Climate Change or UNFCCC was created which established annual conference of Parties (COP) beginning 1995. In COP-3, Kyoto Protocol was negotiated. At **Cancun** in COP-16, an agreement was undertaken to limit global warming to below 2°C (3–6°F) relative to preindustrial level. In COP-18 at Doha (Dec. 2012) a **second commitment** was undertaken to extend the Kyoto Protocol for eight years from 2013–2020. In 2012, a second Earth Summit (Rio + 20) was also held in Rio-de-Janeiro. In COP-21 (2015) held in Paris, it was agreed to limit the global temperature increase to 1.5°C above the pre-industrial level.

7. **Kyoto Protocol** (Dec. 1997). International conference held in Kyoto, Japan obtained commitments from different countries for reducing overall greenhouse gas emissions at a level 5% below 1990 level by 2008–2012.

8. **Beijing Protocol** (1999). The protocol lays down steps to reduce emission of CFCs and other ozone depleting substances. It separates the efforts to be made by developing and developed countries.

Degradation by Improper Resource Utilisation and Maintenance

Pollution is not the only cause of degradation of natural resources. Improper utilisation practices can also lead to degradation of natural resources. Two of such misutilisation of soil resources are as follows :

1. **Soil Erosion and Desertification.** Fertile top soil takes hundreds of years to develop. However, faulty utilisation practices can remove it within a few years. This can convert the area into an arid patch. The common causes are deforestation, overgrazing, overcultivation, leaving tilled soils without seedling and improper irrigation. Soil without a vegetation cover is eroded by both wind and water. A sandy patch is formed.

2. **Waterlogging and Soil Salinity.** Excessive irrigation, Kutch irrigation channels, presence of impermeable underground soil pans and poor drainage result in water logging of soil. A waterlogged soil has poor aeration. As a result there is poor plant growth. Evaporation of water from surface draws salt to the surface. A crust of salt is formed both over surface as well as upper layers of the soil. Such soils become **saline** and unfit for growth of crops.

Deforestation

It is removal, decrease or deterioration of forest cover of an area. In 1900, forests occurred in 7000 million *ha* which were reduced to 2890 million *ha* in 1985 and about 2400 million *ha* in 2000. Tropical forests have come down from 1600 million *ha* to 938 million *ha*. Forest cover has been removed by 40% in tropics but only 1% in temperate areas. Deforestation has been heavy in India. In India, one third of the land was covered by forests in late nineteenth thirties. In 1951 it was only 23%. In 1980s it was 19.4% but is 20.64% in 2003.

Causes. 1. **Jhuming.** It is **slash and burn agriculture** which was prevalent in early periods but even now occurs in some 30 million *ha*. Jhum of N.E. India is called **podu** in A.P., **bewar** or **dahza** in M.P. and **dahi** (firing) in Orissa. Other names are Gudia and Chas. Technically it is known as **shifting cultivation**. In India about 5 lakh hectares of land is cleared every year through lopping, burning the remainder, mixing the ash with soil and sowing the cleared land with crop seeds. The land is used for 2 – 3 years without manuring. This results in nutrient depletion, reduced moisture retention and increased soil erosion. Weeds may grow in such areas, e.g., *Eupatorium*, *Parthenium*, *Eichhornia*. Even otherwise jhumed sites initially encourage the growth of annuals. 2. **Hydroelectric Projects.** Dams, reservoirs and hydroelectric projects submerge forest tracts, killing all plants and animals. 3. **Forest Fires.** Huge forest fires engulfing areas of 40,000 km³ have occurred in Indonesia in 1983 and 1997. 4. **Human Establishments.** There is an ever increasing demand for agricultural land in order to grow more food crops for feeding growing human population. This can be done only through clearing forest areas. More land is also required for building more residential complexes and industrial townships. 5. **Mountain and Forest Roads.** Construction of roads and railways in the hilly forested areas brings about a lot of deforestation, landslides and soil erosion. Large sections are dynamited. This weakens the already fragile mountain system. The fragments pass into valleys and streams. They block flow of water bodies damaging the slopes and causing soil erosion. 6. **Canals.** Sarda Sahayak Canal

Irrigation Project was commissioned in eastern U.P. in 1974 to irrigate 16 lakh hectares of land. In 1987, Singh and Afroz found that seepage from canal has damaged 13,677 houses, harmed 2200 cattle, killed about a million mature Sal trees and put about 1,42,000 hectares of land out of cultivation. **7. Overgrazing.** India with 2.4% geographical area has some 500 million livestock population. Grazing area is only 13 million hectares where one hectare of land supports only 6 livestock heads. The remaining livestock naturally graze in forests trampling seedlings and causing compaction of soil. The latter reduces water storing capacity and increases run off. **8. Requirement of Wood.** It is rising, some 300 million m³ for fuel and 40 million m³ for industry; mostly timber and paper industry. Naturally several million hectares of forest land is stripped to meet this demand. **9. Quarrying and Mining.**

Effects. **1. Shrinking Fuelwood.** In Himalayas a woman spends half the day on collecting fuel. In India, availability of fuel-wood is 58 million m³/yr against requirement of 300 million m³. **2. Reduced Timber.** There is decreased availability of timber and other forest products. **3. Change in Climate.** Deforestation results in reduced rainfall, increased drought, hotter summers and colder winters. **4. Soil Erosion.** Soil is exposed to insolation, dries up and gets eroded by wind and water. It is estimated that 6000 million tonnes of top soil is lost annually in India due to water erosion in the absence of forest cover. **5. Flash Floods.** Soil is unable to retain much rain water. There is little percolation to recharge the aquifers. Flash floods occur during rainy season. 400 million people are affected annually by floods in Indian subcontinent. **6. Siltation.** Rainy season rivulets bring eroded soil and deposit the same on beds of reservoirs (reduces storage of water and power generation) and rivers (may change course). **7. Cyclones.** According to Spencer (1999) mangroves help in dissipating energy of cyclones coming from sea. Cyclone hitting Orissa in 1999 is believed to be due to indiscriminate destruction of mangroves on Orissa coastline. **8. Drought.** There is very little water in rivers during dry season causing drought. **9. Loss of Biodiversity and Germplasm.** **10. Rainfall.** There is decrease in amount and periodicity of rainfall. In drier areas deforestation, therefore, leads to desertification or formation of desert. **11. Global Warming.** Deforestation increases atmospheric CO₂ content by releasing carbon stored in organic matter and reduced primary productivity. **12. Indigenous People.** Tribals living in forests depend upon forests for their survival and culture. Deforestation leads to their uprooting and loss of their livelihood.

Differences Between Deforestation and Desertification

Deforestation	Desertification
1. It is removal, decrease or deterioration of forest cover of an area.	1. It is conversion of former moist and fertile land into arid desert area.
2. Rainfall decreases to only minor extent.	2. Rainfall is less than the potential evaporation.
3. Moderation of temperatures is reduced.	3. Temperature is either high or low.
4. It leads to soil erosion.	4. Desertification is a product of soil erosion.
5. Deforestation often causes flash floods.	5. Floods do not occur.
6. Deforested area can be used variously as cropland, industrial area, residential area, fallow land, etc.	6. Desertified area cannot be put to any use.

Afforestation and Reforestation

As per National Forest Policy (1988), hills should have a forest cover of 67% while in plains it should be 33%. However, actual forest cover in India was 21.02% in 2007. Forest

cover can be increased through afforestation and reforestation. **Afforestation** is growing forest over an area where none existed earlier. **Reforestation** is restoring a forest cover over an area where one existed earlier but was removed at some point of time in the past. The two processes can occur naturally over a vacant area but use of silviculture techniques with due consideration of biodiversity speeds up the formation of forests. A tree plantation movement or **Van Mahotsava** is being carried out in India since 1950. Under this movement, both government and private agencies perform tree plantation during July and February every year.

Two strategies are adopted for meeting the requirement of forest products — conservation forestry and commercial forestry.

(i) **Protection or Conservation Forestry.** (a) Degraded forests are mended through silviculture practices. The forests are allowed to recoup before allowing its exploitation. (b) Certain forests included under sanctuaries and national parks are not allowed to be exploited. (c) Well stocked and mature forests are exploited scientifically.

1. **Sustained Yield Block Cutting.** Cutting is allowed only in nonvulnerable forests at a rate which is equal to their regeneration capacity. 2. **Prevention of Scraping and Litter Removal.** 3. **Advanced Silviculture.** 4. **Control of Weeds.** 5. **Pesticides.** 6. **Fire Fighting Equipment.** 7. **Census.** 8. **Supervision and Surveying.** 9. **Economy in extraction and use of timber.** 10. **Water Shed Protection.** 11. **Alternate source of fuel for villagers.** 12. **Controlled Grazing.** None on steep slopes. 13. **Reserve Forests.** They are forests grown over ecologically fragile areas where our water regimes are also located. Felling of trees and grazing are not allowed.

(ii) **Production or Commercial Forestry.** It is plantation of useful trees and shrubs for meeting the commercial requirements without causing any undue demand on the natural forests. It is of four types— social forestry, urban forestry, agroforestry and production plantation.

(i) **Social Forestry** (started in 1976 by NCA). Raising quick growing multipurpose plants in common village lands for meeting requirement of fodder, firewood and small timber. (ii) **Urban Forestry.** It is plantation of fruit, flower and shade bearing plants in urban areas to reduce pollution and ultimate yield of wood. (iii) **Agroforestry.** It is plantation of multipurpose trees/shrubs/horticulture plants/grasses alongwith crops for stabilising soil, meeting the needs of fodder, fruit and timber of the community. It is of three types — agri-silvicultural, agri-pastoral and agri-silvi-pastoral. In **taungya system**, agricultural crops are grown in between rows of planted trees like Sal and Teak. **Jhum** or **shifting cultivation** is also a traditional system of agroforestry which allows regrowth of forests after clearing and cultivation in an area for a few years. (iv) **Production Plantation.** It is growing of industry required trees on specific, either fallow or free grazing lands. Production plantation decreases pressure on real forests.

Differences Between Afforestation and Agroforestry

<i>Afforestation</i>	<i>Agroforestry</i>
1. Afforestation is planting of trees over bare area.	1. Agroforestry is plantation of trees over agriculture land.
2. Afforestation completely covers the area.	2. Woody plants cover the land partially as they are grown in combination of herbaceous crops either at the same time or in time sequence.

as the **National Pollution Prevention Day** in India to mark the anniversary of the Bhopal gas disaster.

- **6th August**— Hiroshima Day. **9th August** — Nagasaki Day. The United States dropped atomic bomb on 6th August 1945 on Hiroshima and on 9th August 1945 on Nagasaki.
- **NEERI**— National Environmental Engineering Research Institute, Nagpur.
- Water Hyacinth plants choke ponds, lakes

and rivers, therefore, they have become a problem in these water bodies.

- **Milan**, a centre of the Italian industry, is thought to be the most polluted city in the world.
- **Stockholm Convention on Persistent Organic Pollutants (PUPS)**, 2001. Reduction and elimination of production, use and release of 12 persistent chemicals like DDT, aldrin, dieldrin, endrin, polychlorinated biphenyl, chlorodane, heptachlor, toxaphene, furans, heptachlorobenze, etc.

NCERT TEXT BOOK QUESTIONS WITH ANSWERS

1. What are the various constituents of domestic sewage. Discuss the effects of sewage discharge on river.

✓ Domestic sewage is waste water from toilets, kitchens and washings which is passed into sewer system. It contains (i) Fibrous matter (ii) Grit (iii) Colloidal particles (iv) Faecal matter (v) Small sized food leftovers. (vi) Pathogens (vii) Nitrate, phosphate and other salts contained in detergents.

Effects on River

- (i) **BOD**. There is rise in BOD or biological oxygen demand. It reduces the amount of dissolved oxygen.
- (ii) **Disappearance of Fish**. Fish and other clean water aerobic organisms disappear in the area of sewage discharge.
- (iii) **Quality of Water**. Water becomes turbid and odorous. It is unfit for use by humans, animals and industries.

However, after some distance downstream, the water becomes clean again with increased dissolved oxygen and reduced BOD. Fish and other clean water animals appear again.

2. List all the wastes which you generate at home, school or during your trips to other places. Could you very easily reduce ? Which could be difficult or rather impossible to reduce ?

✓ A lot of used up unwanted and discarded materials, (both biodegradable and non degradable) are generated by us. These are to be disposed off properly to reduce pollution. Wastes generated by us are : (i) **At home**, waste paper, old clothes, and leather articles broken crockery, cartons, sweepings, food left overs, (ii) **trash** like waste metal cans, plastic, pet bottles, polyethylene carry bags. (ii) **At School**, Paper, discarded pencils, pens and their refills, card boards, polythene bags, wrappers, fruit peels. (iii) **During a trip**. Paper, plastic bags, bottles, old clothes, remains of fruits and other eatables, cartons, food wrappers, left drink cans, broken bottles and glasses and electronic items. Out of these wastes, the following can not be reduced. Electronic wastes, crockery items, trash (metal cans, polyethylene carry bags, pet bottles and plastic items) are non biodegradable and can not be decomposed by microorganisms. However, they can be recycled or burnt in incinerators or used in open dumping (open landfills). The biodegradable wastes (food wastes, paper, rags) can be reduced easily or with some difficulty by the agency of microbes/decomposers.

3. Discuss the causes and effects of global warming. What measures need to be taken to control global warming ?

✓ Rise in mean temperature of the earth is called **global warming**.

Causes. Global warming is due to presence of excess amount of green house gases in the atmosphere. They do not allow the long wave radiations to escape from earth. These are four major major green house or radioactively active gases — CO_2 , CH_4 , CFCs and N_2O . Their contribution to global warming is 60%, 20%, 14% and 6% respectively.

- (i) **Carbon Dioxide**. The atmospheric concentration has risen from 280 ppm in 1750 to 380 ppm in 2007 due to increased combustion of fossil fuels and reduced absorption by plants caused by deforestation.
- (ii) **Methane**. The concentration has increased from 750 ppb to 1750 ppb between 1750 to 2000AD. The reasons are incomplete combustion, anaerobic decomposition, marshes, paddy fields, cattle and methane chimneys.

- (iii) **Chlorofluorocarbons (CFCs).** They are synthetic, compressible gaseous compounds of carbon and halogens used as propellants in aerosols, refrigerants, fire extinguishers, plastic foams, jet fuels, etc. Their atmosphere concentration is currently 282 ppt.
- (iv) **Nitrous Oxide (N_2O).** Its concentration has risen from 270 ppb to 316 ppb between 1750 and 2000AD. Nitrous oxide is formed during combustion of nitrogen rich fuels, decomposition of nitrogen containing organic compounds, nitrogen fertilizers, denitrification and some industrial processes.

Effects.

- (i) **Global Warming.** Already atmospheric temperature has risen by 2.5°C since 1750. The rise was 0.6°C in the last three decades of 20th century. If the trend continues, 21st century will see a further rise of $1.4-5.8^\circ\text{C}$.
- (ii) **Melting of Snow.** Polar ice caps and mountain snow caps will start melting.
- (iii) **Sea level.** Sea level will rise causing submergence of many islands and coastal areas.
- (iv) **Odd Climatic Changes.** Water precipitation will be reduced. Effects like El Nino will rise. More floods and droughts will become common. Tropics and temperate areas will shift 250-600 km polewards. Global air currents will change.
- (v) **Vegetation.** More deserts will appear in tropics. Many forests will be turned into scrub vegetation.
- (vi) **Food Production.** It will be reduced due to higher rate of respiration, increased number of weeds, pests and pathogens.

Measures to Control Global Warming. (i) Stoppage of CFCs production. (ii) Increase in forest area (iii) Reduced use of fossil fuels (iv) More stress on biological nitrogen fixation. (v) Checking population growth.

4. Write critical notes on the following : (a) Eutrophication (b) Biological magnification (c) Ground water depletion and ways for its replenishment.

✓ (a) **Eutrophication.** Refer to the text.

(b) **Biological Magnification.** It is increase in the concentration of a persistent chemical (e.g., organochlorine like DDT) with the rise in trophic level. The chemical becomes hazardous when its concentration becomes very high. For example, a DDT concentration of 0.003 ppb becomes 0.003 ppm in phytoplankton (1000 concentration), 0.04 ppm in zooplankton (13 times concentration over phytoplankton), 0.5 ppm in small fish (12.5 times as compared to zooplankton), 2.0 ppm in larger fish (four times as compared to smaller fish) and 25 ppm in fish eating birds (12.5 times as compared to larger fish).

(c) **Ground Water Depletion and Its Replacement.** Ground water is being pumped out at an enormous rate for its use in agricultural and urban areas that has resulted in the fall of water table by 10m to 30m and depletion of ground water in Punjab, UP and Tamil Nadu and other parts of the country. The efforts of Megassasy award winner Rajinder Singh in conserving ground water are noteworthy.

By the following ways, ground water can be replenished and recharged (i) **Rain water harvesting.** This is the easiest, cheapest and best method to replenish and recharge ground water. The rain water collected over roof of houses is passed into ground through rain water pipes or may be passed directly in old wells and pumps. The rain water is also stored in tanks (e.g., Johads in Rajasthan, Madakas in Karnataka). Roof water is regularly collected in underground storage room called tank or tanka in several parts of Rajasthan and Gujarat for its regular use throughout the year. Series of deep pits and filter topped wells are dug out in the beds of rain water streams, rivulets and rivers to allow percolation of water to recharge the ground water. (ii) **By sprinkler and sub surface irrigation techniques,** a handsome amount of underground water being used in irrigation, water to recharge the ground water (iv) **Afforestation.**

5. Match the column A and B.

Column A

- (a) Catalytic converter
- (b) Electrostatic precipitator
- (c) Earmuffs
- (d) Land fills

Column B

- (i) Particulate matter
- (ii) Carbon monoxide and nitrogen oxides
- (iii) High noise level
- (iv) Solid wastes

✓ (a) – ii, (b) – i, (c) – iii, d – iv.

- (iii) **Chlorofluorocarbons (CFCs).** They are synthetical, compressible gaseous compounds of carbon and halogens used as propellants in aerosols, refrigerants, fire extinguishers, plastic foams, jet fuels, etc. Their atmosphere concentration is currently 282 ppt.
- (iv) **Nitrous Oxide (N_2O).** Its concentration has risen from 270 ppb to 316 ppb between 1750 and 2000AD. Nitrous oxide is formed during combustion of nitrogen rich fuels, decomposition of nitrogen containing organic compounds, nitrogen fertilizers, denitrification and some industrial processes.

Effects.

- (i) **Global Warming.** Already atmospheric temperature has risen by 2.5°C since 1750. The rise was 0.6°C in the last three decades of 20th century. If the trend continues, 21st century will see a further rise of $1.4-5.8^\circ\text{C}$.
- (ii) **Melting of Snow.** Polar ice caps and mountain snow caps will start melting.
- (iii) **Sea level.** Sea level will rise causing submergence of many islands and coastal areas.
- (iv) **Odd Climatic Changes.** Water precipitation will be reduced. Effects like El Nino will rise. More floods and droughts will become common. Tropics and temperate areas will shift 250-600 km polewards. Global air currents will change.
- (v) **Vegetation.** More deserts will appear in tropics. Many forests will be turned into scrub vegetation.
- (vi) **Food Production.** It will be reduced due to higher rate of respiration, increased number of weeds, pests and pathogens.

Measures to Control Global Warming. (i) Stoppage of CFCs production. (ii) Increase in forest area (iii) Reduced use of fossil fuels (iv) More stress on biological nitrogen fixation. (v) Checking population growth.

4. Write critical notes on the following : (a) Eutrophication (b) Biological magnification (c) Ground water depletion and ways for its replenishment.

✓ (a) **Eutrophication.** Refer to the text.

(b) **Biological Magnification.** It is increase in the concentration of a persistent chemical (e.g., organochlorine like DDT) with the rise in trophic level. The chemical becomes hazardous when its concentration becomes very high. For example, a DDT concentration of 0.003 ppb becomes 0.003 ppm in phytoplankton (1000 concentration), 0.04 ppm in zooplankton (13 times concentration over phytoplankton), 0.5 ppm in small fish (12.5 times as compared to zooplankton), 2.0 ppm in larger fish (four times as compared to smaller fish) and 25 ppm in fish eating birds (12.5 times as compared to larger fish).

(c) **Ground Water Depletion and Its Replacement.** Ground water is being pumped out at an enormous rate for its use in agricultural and urban areas that has resulted in the fall of water table by 10m to 30m and depletion of ground water in Punjab, UP and Tamil Nadu and other parts of the country. The efforts of Megassasy award winner Rajinder Singh in conserving ground water are noteworthy.

By the following ways, ground water can be replenished and recharged (i) **Rain water harvesting.** This is the easiest, cheapest and best method to replenish and recharge ground water. The rain water collected over roof of houses is passed into ground through rain water pipes or may be passed directly in old wells and pumps. The rain water is also stored in tanks (e.g., Johads in Rajasthan, Madakas in Karnataka). Roof water is regularly collected in underground storage room called tank or tanka in several parts of Rajasthan and Gujarat for its regular use throughout the year. Series of deep pits and filter topped wells are dug out in the beds of rain water streams, rivulets and rivers to allow percolation of water to recharge the ground water. (ii) **By sprinkler and sub surface irrigation techniques,** a handsome amount of underground water being used in irrigation, can be saved from going waste. (iii) **Ponds, puddles in villages** should be managed to store rain water to recharge the ground water (iv) **Afforestation.**

5. Match the column A and B.

Column A

- (a) Catalytic converter
- (b) Electrostatic precipitator
- (c) Earmuffs
- (d) Land fills

Column B

- (i) Particulate matter
- (ii) Carbon monoxide and nitrogen oxides
- (iii) High noise level
- (iv) Solid wastes

✓ (a) – ii, (b) – i, (c) – iii, d – iv.

6. Why ozone hole forms over Antarctica ? How will enhanced ultraviolet radiation affect ?

✓ A large amount of ODS (ozone depleting substances) like CFCs, N_2O , halons, SO_2 , CH_4 , Cl^- are released by advanced countries like USA, Japan, European countries. These are released in stratosphere, drift towards poles and reach there before the coming of winter. During winter (temp. $85^\circ C$) ice clouds are formed over Antarctica and no sunrise is received in polar areas. It catalyses release of Cl from CFCs. With the coming of spring season, Cl reacts with ozone in the presence of sunlight and converts O_3 into O_2 , causing ozone depletion/thinning of ozone shield in stratosphere called ozone hole. This hole disappears in summer due to free mixing of air of Antarctica with the rest of the global air.

Effect of Enhanced UV Radiation. (i) Snow blindness or inflammation of cornea (ii) Damage of skin cells and development of skin cancer. (iii) Increased incidence of herpes. (iv) Damage to nucleic acids and proteins. (v) Increased fatality of young animals. (vi) Increased blindness in animals. (vii) Reduced immunity (viii) Decreased photosynthesis (ix) Higher number of cataracts in humans.

7. What measures, as an individual, you would like to reduce environmental pollution ?

✓ The following steps may be taken to reduce pollution, (i) Prevention of noise pollution by using fire crackers/TV/musical instruments at permissible limits. (ii) Do not enjoying in night disco clubs where so called music of more than 100db sound is used. (iii) Reduction in pollution from automobile exhausts by using proper speed and regular servicing and tuning of engines and using catalytic convertors. (iv) Minimum use of fossil fuel. (v) By stopping burning of biomass/straw in fields. (vi) No smoking. (vii) No use of loudspeaker in religious places and marriages particularly at night. (viii) Use of alternate source of energy, particularly solar energy. (ix) Use of electrical chimney in the kitchen to reduce kitchen pollution. (x) Use of natural resources as per need, (xi) No use of polythene bags. (xii) disposal of waste only after treatment. (xiii) proper cremation of dead bodies, preferably by electric crematoria. (xiv) Tree plantation in school, around residence. (xv) Use of CFL bulbs in school and home.

8. Discuss briefly the following : (a) Radioactive wastes (b) Defunct ships and e-wastes (c) Municipal solid wastes.

✓ (a) **Radioactive Wastes.** They are nonusable discards which possess radioactivity. Radioactive wastes are of three types :— (i) **Wastes with Low Level Radioactivity.** Coolant water of atomic reactors and pond water used for cooling spent fuel contain very small amount of radioactivity. This, however, undergoes biomagnification. Irradiation centres, radiotherapy units and laboratories also produce wastes with low level radioactivity. (ii) **Wastes with Intermediate Level Radioactivity.** They are radioactive wastes of many ores which are separated during refinement of minerals. (iii) **Wastes with High Level Radioactivity.** Spent fuel of atomic reactors and leakage from reactors have very high level of radioactivity.

All wastes with radioactivity have to be handled carefully and dumped 500 m deep in earth or inside sea after placing them inside very thick protective containers.

Radioactive wastes are highly dangerous to human beings, animals, microbes and vegetation. They kill all of them. Loss of hair, nails, appearance of deformities, cancers and genetic defects appear due to mutations.

(b) **Defunct Ships and e-wastes.** Refer to the text.

(c) **Municipal Solid Wastes.** They are discarded or left over solid materials from homes, shops, offices, hospitals, sweepings and construction work which are collected and disposed off by municipalities. The term **garbage** is used for organic matter while **rubbish** or **trash** is used for rest of solid wastes. Major components of rubbish are discarded papers, leathers, cloth, rubber, broken crockery, glass articles, cans and other metallic discards, plastic and polythene wastes. Municipal wastes are disposed off as follows :—

(i) **Recycling.** Rag pickers take away all those articles which can be recycled, i.e., metals, plastics, glass, cotton cloth, paper, polythene. (ii) **Composting.** Organic wastes are composed along with sludge from sewage treatment plants. (iii) **Burning.** Organic wastes and hospital wastes can be disposed off through incineration (aerobic heating at $900^\circ - 1300^\circ C$) and pyrolysis (anaerobic burning at $1650^\circ C$). (iv) **Dumping (Land filling).** Solid waste is dumped over low lying area for land filling. In **open dumping** the wastes are burnt or compressed at intervals. In **sanitary dumping** the waste is pulverised, compacted and covered by a layer of earth.

9. Discuss briefly the following (a) Green house gases (b) Catalytic converter (c) Ultraviolet-B.

✓ (a) **Green House Gases (GHGs).** They are gases which allow light rays to pass through but

prevent the passage of long wave infra red radiations, e.g., CO_2 , CH_4 , CFCs, N_2O , water vapours. Because of them, the mean temperature of earth is 15°C . It is similar to warming of green house in temperate areas or interior of a closed car in winter sun. In the absence of green house gases, the temperature of earth would go down to -18°C . Recently the concentration of green house gases has started rising (e.g., CO_2 from 280 ppm in 1750 to 380 ppm in 2007, CH_4 700 ppb in 1750 to 1750 ppb in 2000). Chlorofluorocarbons (CFCs) are product of 20th century. Due to the rise in green house gases the mean temperature of earth has risen by 0.8°C during 20th century. It is called **global warming**. The contribution to global warming is CO_2 — 60%, CH_4 — 20%, CFCs — 14%, N_2O — 6%. Though high CO_2 concentration is beneficial to C_3 plants in increasing photosynthesis, the net effect of higher GHGs will be disastrous. (i) Melting of polar ice caps and mountain snow caps resulting in rising of sea level threatening submergence of many islands and coastal areas. (ii) Cooling and shrinkage of upper layers of atmosphere disrupting radio-communications. (iii) Odd climate changes like El Nino. (iv) Increased floods and drought. (v) Decreased food production. (vi) Higher number of diseases. (vii) Death of many temperate trees.

- (b) **Catalytic Converter**. It is device having platinum palladium and rhodium catalysts which is fitted into automobiles for :— (i) Complete oxidation of unburnt hydrocarbons. (ii) Oxidation of CO to CO_2 . (iii) Conversion of nitrogen oxides to nitrogen. The only precaution required is not to use gasoline having lead as lead inactivates the catalysts of the converter.
 - (c) **Ultraviolet -B**. It is part of ultra violet radiation having a wavelength of 280-320nm. UV-B is quite harmful to the organisms. Ozone layer in the stratosphere absorbs 50% of total UV-B. In ozone depletion/thinning of ozone layer, more UV-B radiations reach the earth. A 5% loss of ozone, results in a 10% increase in UV-B radiation. This is more over equator than poles due to thinning of ozone shield over equator. In humans the increased UV-radiation increases the incidence of snow blindness, cataract, skin cancer (including melanoma), ageing of skin, harmful mutations, formation of thymine dimers and partial suppression of immune system. Photosynthesis is inhibited in phytoplankton thereby affecting food chain.
10. Discuss the role of women and communities in protection and conservation of forests.
 - ✓ Refer to the text for role of Bishnois, Chipko movement and Joint forest management.
 11. What initiatives were taken for reducing air pollution in Delhi ? How air quality improved in Delhi ?
 - ✓ Refer to the text.

TEXT QUESTIONS

One Mark Questions (With Answers)

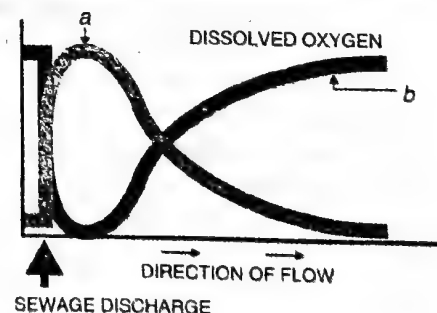
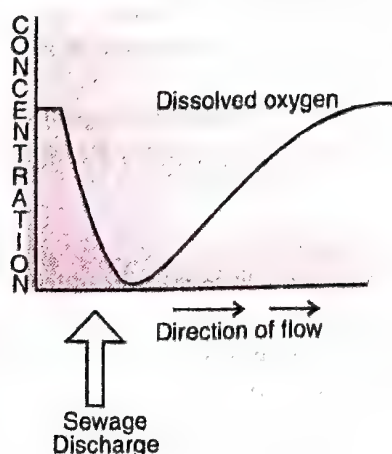
1. Define contamination ?
 - ✓ Contamination is presence of harmful organisms or their products causing disease or discomfort.
2. Define quantitative pollutants.
 - ✓ Ingredients whose concentration reach beyond a threshold value in the environment become pollutants, e.g., CO, CO_2 , nitrogen oxides.
3. What constitutes smog ?
 - ✓ Smog is dark or opaque fog which is formed by the dust and smoke particles causing condensation of water vapours around them as well as attracting chemicals like SO_2 , H_2S , NO_2 etc.
4. At which concentration carbon monoxide can cause headache and giddiness ?
 - ✓ At 100 ppm concentration.
5. At what stage jhuming can be harmful ?
 - ✓ When jhuming is done in less than ten years, it destroys forests and causes soil erosion.
6. Name the unit to measure noise pollution ?
 - ✓ **Deci Bels** (dB).
7. Write any two sources of pollution without human intervention ?
 - ✓ Volcanic eruptions, Forest fires, Cyclones and Floods.
8. Name any one of the green house gases
 - ✓ carbon dioxide
9. Expand the term ODS
 - ✓ Ozone depleting substances.

One Mark Questions (Without Answers)

10. In which part of atmosphere, ozone layer is found ?
11. BOD of two samples of water A and B were 120 mg/l and 400 mg/l respectively. Which sample is more polluted. (CBSE 2009)
12. How is snow blindness caused in humans ? (CBSE 2010)
13. Mention the information that health workers derive by measuring BOD of a water body. (CBSE 2010)
14. How do algal blooms affect the life in water bodies ? (CBSE 2011)
15. Write the unit used for measuring ozone thickness. (CBSE 2011)
16. Why is it desirable to use unleaded petrol in vehicles fitted with catalytic converters? (CBSE 2012)
17. Why is the use of unleaded petrol recommended for motor vehicles equipped with catalytic converters? (CBSE 2013)
18. State the cause of accelerated eutrophication. (CBSE 2014)
19. Name the green house gases that contribute to total global warming. (CBSE 2014)
20. Mention two advantages for preferring CNG over diesel as an automobile fuel. (CBSE 2016)
21. Excessive nutrients in a fresh water body cause fish mortality. Give two reasons. (CBSE 2016)

Two Mark Questions

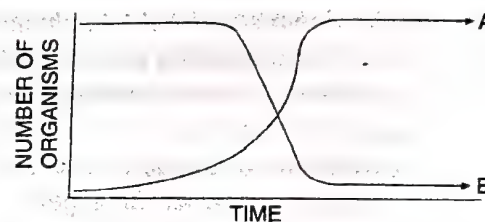
1. What are the effects of ultraviolet radiations on humans ?
✓ (i) Increased chances of cataract (ii) Damage to corneal cells (iii) Injury to germinative layer, rupture of subcutaneous capillaries, blisters and skin cancer (iv) Reduced functioning of immune system.
2. Write down effects of oil pollution on plants and animals ?
✓ (i) Oil spreading on the surface of water prevents its oxygenation. Rather, it depletes the small quantity of oxygen present in water for its own degradation (ii) Oil pollution inhibits plankton growth and photosynthetic activity of other aquatic plants (iii) Animal life is destroyed due to reduced availability of oxygen, food and toxic effects of oil (iv) Oil spilled over the water surface may catch fire and hence kill all organic life (v) Detergents used to clean oil spill are equally harmful. This happened during Torrey Canyon accident on British Coast (1969) (vi) Sea birds smeared with oil fall sick and die.
3. Explain accelerated eutrophication. Mention any two consequences of this phenomenon. (CBSE 2009)
4. A Crane had DDT level of 5 ppm in its body. What would happen to the population of such birds? Explain giving reasons. (CBSE 2009)
5. Explain the cause of algal bloom in a water body. How does it affect an ecosystem. (CBSE 2009)
6. How do automobiles fitted with catalytic converters reduce air pollution? Suggest the best fuel for such vehicles. (CBSE 2009)
7. Mention the major cause of air pollution in metro cities. Write any three ways by which it can be reduced. (CBSE 2010)
8. Mention how e-waste is produced and disposed off. Write the solution for its treatment. (CBSE 2010)
9. Explain giving reasons the cause of appearance of peaks 'a' and 'b' in the graph. (CBSE 2010)
10. Chlorofluorocarbons (CFCs) are widely used as refrigerants. Then why it is suggested to reduce their emission as far as possible ? Explain (CBSE 2010)
11. Study the graph. Explain how is oxygen concentration affected in the river when sewage is discharged in it. (CBSE 2011)



12. How did Alimed Khan, plastic sacks manufacturer from Bangalore, solve the ever-increasing problem of accumulating plastic waste ? (CBSE 2012)
13. Name any two sources of e-wastes and write two ways for their disposal. (CBSE 2013)
14. What is joint forest management ? How can it help in conservation of forests ? (CBSE 2015)
15. Explain the relationship between CFCs and ozone in the stratosphere. (CBSE 2016)
16. List the events that reduce the biological oxygen demand (BOD) of a primary effluent during sewage treatment. (CBSE 2016)
17. List four benefits to human life by eliminating the use of CFCs. (CBSE 2017)
18. Plenty of algal bloom is observed in a pond in your locality.
(a) Write what has caused this bloom and how does it affect the quality of water.
(b) Suggest a preventive measure. (CBSE 2017)

Three Mark Questions (With Sample Answer)

1. Explain any three measures which will control vehicular air pollution in Indian cities. (CBSE 2009)
2. Particulate and gaseous pollutants along with harmless gases are released from the thermal power plants (i) Name any two harmless gases released (ii) Name the most widely used device of removing particulate pollutants from the air. Explain how the device is used. (CBSE 2009)
3. (i) State the consequence if the electrostatic precipitator of a thermal plant fails to function.
(ii) Mention any four methods by which the vehicular air pollution can be controlled. (CBSE 2011)
4. How have human activities caused desertification? Explain. (CBSE 2013)
5. How does algal bloom destroy the quality of a fresh water body? Explain. (CBSE 2013)
6. Two types of aquatic organisms in a lake show specific growth patterns as shown, in a brief period of time. The lake is adjacent to an agricultural land extensively supplied with fertilizers. (a) Name the organisms depicting the patterns A and B. (b) State the reason for the growth pattern seen in A (c) Write the effects of the growth patterns seen above. (CBSE 2014)
7. With the help of a flow chart, show the phenomenon of biomagnification of DDT in an aquatic food chain. (CBSE 2015)
8. With the help of a flow chart exhibit the events of eutrophication. (CBSE 2015)
9. "Determination of biological oxygen demand (BOD) can help in suggesting the quality of a water body". Explain. (CBSE 2015)
10. (a) Name any two places where it is essential to install electrostatic precipitators. Why it is required to do so ?
(b) Mention one limitation of electrostatic precipitator. (CBSE 2016)



Five Mark (Long Answer Type) Questions

1. What is meant by ozone shield ? Name two ozone depleting substances. How do the ozone depleting substances affect the ozone shield ? Write one damaging effect of ozone depletion on humans and plants respectively. (CBSE 2005 Comptt.)
2. List any four factors which determine the amount of dissolved oxygen in water. Explain in brief the harmful effects of nitrate, fluoride and arsenic salts in ground water on humans. (CBSE 2005 Comptt.)
3. Write in detail the ill effects of air pollution.
4. (a) What is El Nino effect ? Explain how it accounts for biodiversity loss.
(b) Explain any three measures that you as an individual would take to reduce environmental pollution. (CBSE 2011)
5. (a) What depletes ozone in the stratosphere ? How does this affect human life ?
(b) Explain biomagnification of DDT in an aquatic food chain. How does it affect the bird population? (CBSE 2012)

Value Based Question

1. Since October 02, 2014 "Swachh Bharat Abhiyan" has been launched in our country. (a) Write your views on this initiative giving justification. (b) As a biologist name two problems that you may face while implementing the programme in your locality. (c) Suggest two remedial methods to overcome these problems.

- ✓ (a) Insanitary conditions are the major cause of several diseases. Air, water, edibles all get contaminated by such conditions. Swachh Bharat Abhiyan is meant for keeping our environment clean and hygienic disposal of all wastes.
- (b) (i) Apathy of residents towards proper disposal of their garbage. (ii) Non-cooperation by residents in separation of biodegradable and non-biodegradable wastes. (iii) Collection, transportation and disposal of garbage.
- (c) (i) Vigorous campaigning for creating awareness about cleanliness and proper disposal of garbage and telling them about the consequences of unhygienic conditions. (ii) Telling the residents about separation of garbage at the source. (iii) Keeping touch with the authorities about timely collection, prevention of spills during transportation and free distribution of non-biodegradable articles to rag pickers for small help in keeping the environment clean.
2. What is Van Mahotsava ? What is its social impact.
- ✓ Van Mahotsava is a tree plantation drive undertaken by both government and nongovernment agencies including schools and colleges. It is performed twice a year during July and February when the climate is favourable and the soil has sufficient moisture.
- Tree plantation drive not only replaces the trees felled during development but also adds to the number already existing. It shall
- (i) Keep the air cleaner by removal of dust and pollutants.
 - (ii) Add to the oxygen content of the air.
 - (iii) Reduction in CO_2 content.
 - (iv) Reduction in noise by acting as green muffler.
 - (v) Moderating climate.
 - (vi) Bringing us near to nature as trees will invite a number of small animals to take shelter.
 - (vii) Inculcation of the spirit of comradeship and service to nation as well as nature.
3. What are joint forest management committees? What values do they depict?
- ✓ Joint forest management committees (JFMCs) are village or tribe level forest management committees that comprise all the willing adult members with respective forest or block forest officer being member secretary, an elected president and an executive body. They are engaged in development and protection of forests, choice of species to be planted, suggesting physical and financial targets, harvesting of forest produce and sharing the profits. The members also get the minor forest produce almost free. There is no pilferage, no over-exploitation, no monoculture and no damage to environment. The tribals are able to get gainful employment while the forests are given traditional as well as scientific support.
4. How has plastic waste been converted into resource by Ahmed Khan of Bengaluru? What value can be learnt from it?
- ✓ Ahmed Khan was a plastic sack manufacturer of Bengaluru. He used to purchase waste plastic and recycle the same into manufacture of plastic sacks. The process was quite cumbersome and the product was not of good quality. He converted waste plastic into a fine powder called **polyblend**. He mixed his polyblend with bitumen and found that road carpeted with the mixture had better water repellent property and that the road life increased by three times. Today many hundred kilometres of roads have been carpeted by bitumen-polyblend mixture. The rag pickers could also earn a better price for plastic waste.
- The conversion of plastic waste into polyblend clearly shows that wastes can be changed into a resource through human efforts. This will solve the problem of huge wastes being generated by modern human society.
5. Public all over India is very much concerned about the deteriorating air quality in large parts of North India. Alarmed by this situation, the "Residents' Welfare Association" of your locality organised an awareness programme entitled "Bury not Burn". They invited you, being a biology student to participate.
- (a) How would you justify your arguments that promote burying and discourage burning ? (Give two reasons). (b) With the help of flow charts, one for each practice, depict the chain of events that follow.
- (CBSE 2017)
- ✓ There is a tendency to burn the biodegradable wastes in order to quickly dispose them off. Biodegradable wastes are generated in very large amounts in homes, eateries, vegetable markets, fruit markets, parks and agricultural operations. They contain a lot of nutrients bound in their organic matter. (i) Burning results in wastage of nutrients contained in organic matter. (ii) Burning causes air pollution and reduces visibility due to smoke and pollutant gases. (iii) Humans suffer from a number of pollution related ailments, especially the respiratory diseases. (iv) It adds to global warming.

Therefore, it is important that biodegradable wastes should not be burnt but converted into useful resource in the form of manure and compost. This can be done by burying the wastes in pits with or without the inoculation of earthworms (vermicompost).

(i) Wastes in pits → cover by thin soil → Decomposition → Manure or compost → Added to soil for increasing its crumb structure, aeration, hydration and mineral fertility.

(ii) Wastes in pits → Fragmentation → Decomposition → Humus → Added to soil for increasing its crumb structure and fertility.

Multiple Choice Questions

- (1) Ozone layer occurs in
(a) troposphere (b) stratosphere (c) mesosphere (d) exosphere. (DPMT 2008)
- (2) Which one is nonbiodegradable
(a) sewage (b) market garbage (c) livestock waste (d) DDT. (DPMT 2008)
- (3) BOD is a measure of
(a) Industrial wastes passed into water bodies (b) amount of carbon monoxide combined with haemoglobin (c) extent of pollution with organic matter (d) amount of oxygen required by plants during night. (AIIMS 2008)
- (4) Which one is correct percentage of green house gases
(a) Methane – 20%, N_2O – 18% (b) CFCs – 14%, Methane – 20% (c) CO_2 – 40%, CFCs – 30% (d) N_2O – 6%, CO_2 – 86%. (CBSE 2008)
- (5) Which particulate size is most harmful?
(a) 1.0 μm or less (b) 1.5 μm or less (c) 2.5 μm or less (d) 5.2 μm – 2.5 μm . (CBSE 2008)
- (6) Global agreement to reduce release of ODS is
(a) Vienna Convention (b) Rio de Janeiro Conference (c) Kyoto Protocol (d) Montreal Protocol. (CBSE 2009)
- (7) BOD in river water
(a) Remains unchanged when algal bloom occurs (b) Increases when sewage gets mixed up with river water (c) Has no relationship with concentration of oxygen in water (d) Give a measure for *Salmonella* in water. (CBSE 2009)
- (8) Biomagnification of DDT causes decline in bird population by
(a) Disturbing Ca metabolism (b) Thinning of egg shells (c) Premature breaking of egg shells (d) All the above. (HP PMT 2010)
- (9) dB is a standard abbreviation used for the quantitative expression of
(a) A particular pollutant (b) The dominant *Bacillus* in a culture (c) A certain pesticide (d) The density of bacteria in a medium. (CBSE 2010)
- (10) Which one of the following statements is **wrong** in case of Bhopal tragedy
(a) Radioactive fallout engulfed Bhopal (b) It took place in the night of December 2/3, 1984 (c) Methyl isocyanate gas leakage took place (d) Thousands of human beings died. (CBSE 2011)
- (11) Consider the following statements (i-iv) about organic farming (i) Utilizes genetically modified crops like Bt Cotton (ii) Uses only naturally produced inputs like compost (iii) Does not use pesticides and urea. (iv) Produces vegetables rich in vitamins and minerals. Which of the above statements are correct.
(a) ii and iii only (b) i and ii (c) ii, iii and iv (d) iii and iv only. (CBSE Mains 2011)
- (12) In an area where DDT had been used extensively, the bird population declined significantly due to (a) Birds stopped laying eggs (b) earthworms disappeared from the area (c) many of the birds eggs did not hatch (d) snakes started feeding exclusively on birds. (CBSE 2012)
- (13) Which one is wrong statement? (a) Ozone in upper part of atmosphere is harmful to animals (b) Green house effect is a natural phenomenon (c) Eutrophication is a natural phenomenon in freshwater bodies (d) Most of the forests have been lost in tropical area. (CBSE 2012)
- (14) Global warming can be controlled by (a) Increasing deforestation, reducing efficiency of energy use of fossil fuel (b) Reducing deforestation, cutting down use of fossil fuel (c) Reducing deforestation, increasing use of fossil fuel (d) Increasing deforestation, slowing down the growth of human population. (NEET 2013)
- (15) Kyoto Protocol was endorsed at (a) COP – 4 (b) COP – 3 (c) COP – 5 (d) COP – 6. (NEET 2013)

- (16) 'Kyoto protocol' is a multinational treaty for (a) phasing out green house gases (b) conservation of biodiversity (c) controlling ozone destroying substances (d) management of hazardous wastes. (WB 2014)
- (17) The zone of atmosphere in which ozone layer is present is (a) Troposphere (b) Stratosphere (c) Mesosphere (d) Ionosphere. (CBSE 2014)
- (18) Which of the following is the most suitable indicator of SO_2 pollution in the environment? (a) Lichens (b) Conifers (c) Algae (d) Fungi. (CBSE 2015)
- (19) Eutrophication of water bodies leading to killing of fishes is mainly due to nonavailability of (a) food (b) light (c) essential minerals (d) oxygen. (CBSE 2015)
- (20) Depletion of which gas in the atmosphere can lead to an increased incidence of skin cancers? (a) Methane (b) Nitrous oxide (c) Ozone (d) Ammonia. (NEET-I 2016)
- (21) Biochemical oxygen demand may not be good index for water bodies receiving effluents from (a) sugar industry (b) Domestic sewage (c) Dairy industry (d) Petroleum industry. (NEET-II 2016)
- (22) Which one of the following statements is not valid for aerosols? (a) They are harmful to human health (b) They alter rainfall and monsoon patterns (c) They cause increased agricultural activity (d) They have negative impact on agriculture land. (NEET 2017)

Assertion Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as—
 (a) If both A and R are true and R is the correct explanation of A
 (b) If both A and R are true and R is not the correct explanation of A
 (c) If A is true but R is false
 (d) If both A and R are false.

- Assertion.** Methane is component of green house gases contributing to about 20% of global warming.
Reason. Introduction of multipoint fuel injection engines in automobiles has decreased methane content in exhausts. (AIIMS 2005)
 A B C D
- Assertion.** Suspended particulate matter (SPM) is an important pollutant released by diesel vehicles.
Reason. Catalytic converters greatly reduce pollution caused by automobiles. (AIIMS 2005)
 A B C D
- Assertion.** Presently the global atmosphere is warming up.
Reason. The depletion of stratospheric ozone layer has resulted in increase in ultraviolet radiations reaching the earth. (AIIMS 2005)
 A B C D
- Assertion.** Nitrate pollution causes blue-baby syndrome.
Reason. Nitrite combines with haemoglobin to form nonfunctional met-haemoglobin.
 A B C D
- Assertion.** The global mean temperature has increased by 0.6°C during 20th century.
Reason. There has been a progressive increased combustion of fossil fuels generating more green house gases.
 A B C D
- Assertion.** Inhabitants close to busy airports are likely to experience health hazards.
Reason. Sound levels of jet aeroplanes usually exceed 160 dB.
 A B C D
- Assertion.** Deforestation is one main factor contributing to global warming.
Reason. Besides CO_2 , two other gases, methane and CFCs, are also included under green house gases. (AIIMS 2006)
 A B C D
- Assertion.** Concentration of methane in the atmosphere has more than doubled in the last 250 years.
Reason. Wetlands and rice fields are the major source of methane. (AIIMS 2006)
 A B C D
- Assertion.** Inhabitants close to very busy airports experience health hazards.
Reason. Sound level of jet aeroplanes usually exceeds 160 dB. (AIIMS 2008)
 A B C D

10. **Assertion.** Amount of biodegradable present in water is measured by BOD organic matter.
Reason. During biodegradation of organic compounds, oxygen is released. (AIIMS 2011)
 A B C D
11. **Assertion.** Algal blooms occur in nutrient poor water.
Reason. Algal blooms make water unfit for human consumption but cause enormous growth of fish. (AIIMS 2011)
 A B C D
12. **Assertion.** Secondary air pollutants are formed by interaction among primary pollutants and are more toxic.
Reason. DDT is a secondary air pollutant. (AIIMS 2014)
 A B C D
13. **Assertion.** BOD of river polluted by sewage is more than 20 ppm.
Reason. Polluted river contains excess of organic matter. (AIIMS 2015)
 A B C D
14. **Assertion.** Presence of large amounts of nutrients in water body causes excessive growth of planktonic algae.
Reason. It is due to biomagnification. (AIIMS 2015)
 A B C D

ANSWERS

Matching Type Questions

a — ii, b — i, C — iii, d — iv

Multiple Choice Questions

(1) —b (2) —d (3) —c (4) —b (5) —c (6) —d (7) —b (8) —d (9) —a (10) —a
 (11) —a (12) —c (13) —a (14) —b (15) —b (16) —a (17) —b (18) —a (19) —d (20) —c
 (21) —d (22) —c

Assertion Type Questions

(1) —B (2) —B (3) —B (4) —A (5) —A (6) —C (7) —B (8) —B (9) —A (10) —C
 (11) —D (12) —C (13) —A (14) —C

**Subjective
NCERT Exemplar
Problems
(Solved)**

Chapter—1

REPRODUCTION IN ORGANISMS

Very Short Answer Type Questions

1. **Mention two inherent characteristics of *Amoeba* and Yeast that enable them to reproduce asexually.**
 Ans. (i) They are unicellular organisms. (ii) They have a simple body structure.
2. **Why do we refer to offspring formed by asexual method of reproduction as clones ?**
 Ans. Offspring formed from asexual reproduction are called clones as they resemble one another both morphologically and genetically.
3. **Although potato tuber is an underground part, it is considered as a stem. Give two reasons.**
 Ans. (i) Like stem, the tuber bears nodes and internodes.
 (ii) The nodes bear buds which can grow to form leaf shoots (= plantlets).
4. **Between an annual and a perennial plant, which one has a shorter juvenile phase? Give one reason.**
 Ans. Annual plant has a shorter juvenile phase since it has a shorter life span of less than a year while perennial plant has a longer life span of several years.
5. **Rearrange the following events of sexual reproduction in the sequence in which they occur in a flowering plant : embryogenesis, fertilization, gametogenesis, pollination.**
 Ans. Gametogenesis, pollination, fertilization, embryogenesis.
6. **The probability of fruit set in a self pollinated bisexual flower of a plant is far greater than a dioecious plant. Explain.**
 Ans. In a self pollinated bisexual flower, fertilization and fruit formation are ensured as no external agency is required. In dioecious plant, males do not bear fruits while females depend for fruit formation upon an external pollinating agency.
7. **Is the presence of large number of chromosomes in an organism a hindrance to sexual reproduction ? Justify your answer by giving suitable reason.**
 Ans. Large number of chromosomes are a hindrance to sexual reproduction because of
 (i) Difficulty of zygotene formation in small space. (ii) Accommodation problem of large number of bivalents over the equator. (iii) Disturbance in disjunction of so many homologous chromosomes. (iv) Formation of large number of nonfunctional gametes.
8. **Is there a relationship between the size of an organism and its life span ? Give two examples in support of your answer.**
 Ans. No, there is no relationship between size and life span of organisms. Large sized tiger and small sized dog both live for about 20 years. Very large sized elephant has a life span of upto 90 years. On the other hand small-sized tortoise lives for 200 years.

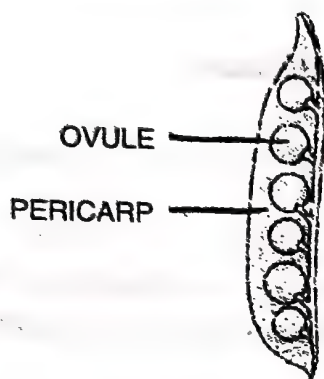
9. In the given figure, the plant bears two different types of flowers marked 'A' and 'B'. Identify the types of flowers and state the type of pollination that will occur in them.

Ans. 'A' — Chasmogamous (open) flower — cross pollination
'B' — Cleistogamous (closed) flower — self pollination.

10. Give reasons as to why cell division cannot be a type of reproduction in multicellular organisms.

Ans. In multicellular organisms, cell division does not divide the body into daughters (as in unicellular organisms) but instead adds to the number of cells to the body so as to increase its size.

11. In the given figure, mark the ovule and pericarp.



Ans.

12. Why do gametes produced in large numbers in organisms exhibiting external fertilization?

Ans. In external fertilization, as in water, gametes are given out in a large area. There are fewer chances that male and female gametes meet and fuse. Therefore, they are produced in large number so that atleast a few of them fuse and form offspring.

13. Which of the following are monoecious and dioecious organisms : Earthworm, *Chara*, *Marchantia*, Cockroach ?

Ans. (a) Earthworm — Monoecious. (b) *Chara* — Monoecious.
(c) *Marchantia* — Dioecious. (d) Cockroach — Dioecious.

14. Match the organisms given in column A with the vegetative propagules in column B.

Column A	Column B
(i) <i>Bryophyllum</i>	(a) Offset
(ii) <i>Agave</i>	(b) Eyes
(iii) Potato	(c) Leaf buds
(iv) Water Hyacinth	(d) Bulbils

Ans. (i) — (c); (ii) — (d); (iii) — (b); (iv) — (a).

15. What do the following parts of a flower develop into after fertilization? (a) Ovary — (b) Ovules —

Ans. Ovary — Fruit. (b) Ovules — Seeds.

Short Answer Type Questions

1. In haploid organisms that undergo sexual reproduction, name the stage in the life cycle when meiosis occurs. Give reasons for your answer.

Ans. Stage of Meiosis. Germination of zygote.

Reason. Zygote is diploid while the organism is haploid. As the organism develops through germination of zygote, meiosis must occur in the zygote itself to form haploid cells.

2. **The number of taxa exhibiting asexual reproduction is drastically reduced in higher plants (angiosperms) and higher animals (vertebrates) as compared with lower groups of plants and animals. Analyse the possible reasons for this situation.**

Ans. Higher plants (angiosperms) and higher animals (vertebrates) have a complex elaborate structural organisation and an efficient mechanism of sexual reproduction. They have long life span and, therefore, require a lot of variations to cope with environmental changes. This is not possible with asexual reproduction which produces only genetic clones. Sexual reproduction gives rise to numerous variations due to chance separation of chromosomes during gametogenesis, crossing over and chance combination of chromosomes during fertilization. Therefore, higher plants and animals have resorted to reproduction by sexual method.

3. **Honeybees produce their youngones only by sexual reproduction. Inspite of this, in a colony of bees we find both haploid and diploid individuals. Name the haploid and diploid individuals in the colony and analyse the reasons behind their formation.**

Ans. Honeybee colony has three types of castes — haploid drones, diploid fertile queen and diploid sterile workers. Haploid drones are males which are formed from unfertilized eggs. Diploid queen and workers are females. They are produced from diploid fertilized eggs. The difference between the two is in their diet.

4. **With which type of reproduction do we associate the reduction division ? Analyse the reason for it.**

Ans. Reduction division or meiosis is associated with sexual reproduction. Sexual reproduction involves fusion of gametes to form zygote that grows to form the offspring.

- (i) Fusion of gametes causes doubling of chromosomes. Therefore, the gametes must be haploid.
- (ii) Haploid gametes are formed from diploid cells. This is possible only through meiosis.
- (iii) Reduction division maintains the constancy of chromosome number in the organisms generation after generation.

5. **Is it possible to consider vegetative propagation observed in certain plants like *Bryophyllum*, Water Hyacinth, Ginger, etc. as a type of asexual reproduction ? Give two/three reasons.**

Ans. Vegetative reproduction is a type of asexual reproduction as (i) A vegetative part of the plant functions as a propagule to produce new plant.

- (ii) There is no gamete formation.
- (iii) Vegetative reproduction, like asexual reproduction, is uniparental. The new individuals are clones of the parent.

6. **Fertilization is not an obligatory event for fruit production in certain plants. Explain the statement.**

Ans. It is true because no fertilization occurs in seedless fruits like Banana, Navel Orange and some varieties of grapes. Even in others, fruits can develop without fertilization if their flowers are sprayed with growth hormone like auxin or gibberellin. In such cases the ovules do not develop into seeds.

7. **In a developing embryo, analyse the consequences if cell divisions are not followed by cell differentiation.**

Ans. Cell differentiation is a must for formation of tissues and organs. In the absence of cell differentiation, the developing embryo will become a mass of similar cells. There would not be any plumule, radicle, cotyledons or embryo axis. A new plant will not be formed from such an embryo.

8. List the changes observed in an angiosperm flower subsequent to pollination and fertilization.

Ans. (i) Pollen grain germinates over the stigma and forms a pollen tube carrying two male gametes. (ii) Pollen tube reaches ovary and enters an ovule through one of its synergids. (iii) Fertilization produces a diploid zygote and triploid primary endosperm cell. (iv) Zygote produces embryo. (v) Primary endosperm cell forms endosperm. (vi) Ovule is transformed into seed. (vii) Ovary is changed into fruit. (viii) Stigma, style, sepals, petals and stamens wither and fall down.

9. Suggest a possible explanation why the seeds in a pea pod are arranged in a row, whereas those in tomato are scattered in the juicy pulp.

Ans. Arrangement of seeds inside a fruit depends upon the type of placentation and the growth of placental axis. In Pea, placentation is marginal. The placenta does not grow. Therefore, seeds remain arranged in a row. In Tomato, placentation is axile around the middle axis. The placentae grow and become pulpy during fruit formation. As a result seeds get scattered in the pulpy mass.

10. Draw the sketches of zoospore and a conidium. Mention two dissimilarities between them and at least one feature common to both structures.

Ans. Draw Fig. 1.17 A and B. **Similarity.** Both are asexual reproductive structures.
Differences. (i) Conidia are nonflagellate while zoospores are flagellate. (ii) Conidia are formed exogenously in chains while zoospores are formed endogenously in a group.

Long Answer Type Questions

- Enumerate the differences between asexual and sexual reproduction. Describe the types of asexual reproduction exhibited by unicellular organisms.
- Do all the gametes formed from a parent organism have the same genetic composition (identical DNA copies of the parental genome)? Analyse the situation with the background of gametogenesis and provide or give suitable explanation.
- Although sexual reproduction is a long drawn, energy-intensive complex form of reproduction, many groups of organisms in Kingdom Animalia and Plantae prefer this mode of reproduction. Give atleast three reasons for this.
- Differentiate between (a) oestrus and menstrual cycles; (b) ovipary and vivipary. Cite an example for each type.
- Rose plants produce large, attractive bisexual flowers but they seldom produce fruits. On the other hand a tomato plant produces plenty of fruits though they have small flowers. Analyse the reasons for failure of fruit formation in rose. Both these plants - rose and tomato - both selected by human beings for different characteristics, the need to produce seeds.

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

Chapter—2

SEXUAL REPRODUCTION IN FLOWERING PLANTS

Very Short Answer Type Questions

1. Name the component cells of the egg apparatus in an embryo sac.

Ans. One egg or oosphere and two synergids or help cells.

2. Name the part of the gynoecium that determines the compatible nature of pollen grain.

Ans. Stigma.

3. Name the common function that cotyledons and nucellus perform.

Ans. Nourishment (embryo by cotyledons and embryo sac by nucellus).

4. Complete the following flow chart.



Ans. Generative Cell.

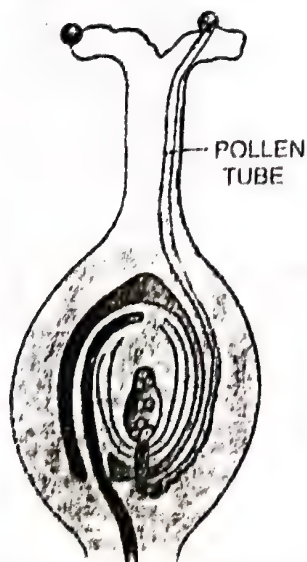
5. Indicate the stages where meiosis and mitosis occur (1,2 or 3) in the flow chart.



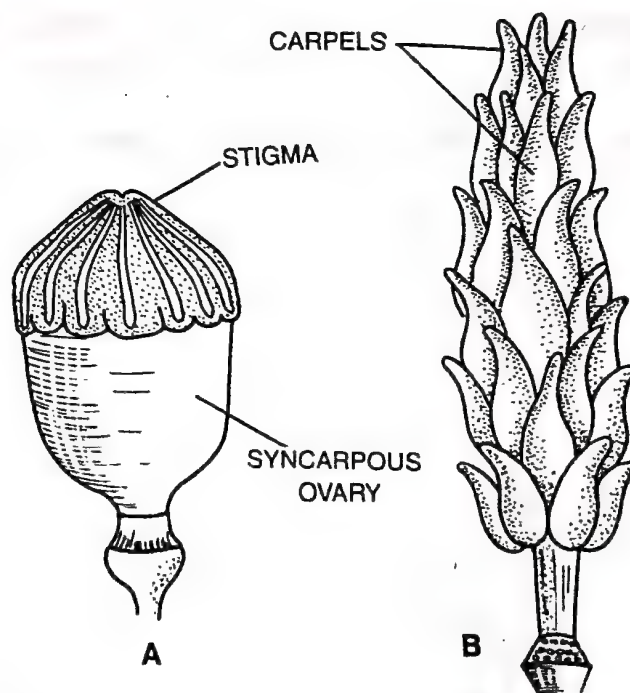
Ans. 1. Meiosis. 2. Mitosis.

6. In the given diagram show the path of pollen tube from the pollen on the stigma into the embryo sac. Name the components of egg apparatus.

Ans. Components of Egg Apparatus. One oosphere and two synergids.



7. Name the parts of the pistil which develop into fruit and seeds.
Ans. Ovary develops into fruit while ovules develop into seeds.
8. In case of polyembryony, if an embryo develops from the synergid and another from nucellus. Which is haploid and which is diploid?
Ans. Embryo developed from synergid is haploid while the embryo formed from nucellus is diploid.
9. Can an unfertilized, apomictic embryo sac give rise to a diploid embryo? If yes, then how?
Ans. An embryo sac can form a diploid embryo through apomixis if it is itself diploid as when it develops from a diploid nucellar or integument cell.
10. Which are the three cells found in a pollen grain when it is shed at the three celled stage?
Ans. One vegetative (tube) cell and two male gametes.
11. What is self incompatibility?
Ans. It is inability of certain otherwise viable gametes of the same strain to fuse with each other and produce fertile offspring.
12. Name the type of pollination in self-incompatible plants.
Ans. Cross pollination.
13. Draw the diagram of a mature embryo sac and show its 8-nucleate, 7-celled nature. Show the following parts : antipodals, synergids, egg, central cell, polar nuclei.
Ans. Drawn and Label Fig. 2.15 from Elementary Biology.
14. Which is the triploid tissue in a fertilised ovule? How is the triploid condition achieved?
Ans. Endosperm. The triploid condition is achieved in the primary endosperm cell due to triple fusion or fusion of two polar nuclei of central cell with one nucleus of a male gamete.
15. Are pollination and fertilization necessary in apomixis? Give reasons.
Ans. No. Apomixis is formation of embryo without involving the fusion of gametes. Instead of developing from a zygote, an apomictic embryo develops directly from a cell of nucellus, integument, egg or even synergid. Therefore, neither pollination nor fertilization is required.
16. Identify the type of carpels with the help of diagrams given below.



- Ans.** (A) Polycarpellary syncarpous. (B) Polycarpellary apocarpous.

17. How is pollination carried out in water plants ?

Ans. Water plants carry out hydrophily or pollination through the agency of water. Their pollen grains are without exines. They float in water. The stigma is sticky to catch the pollen grains. (Anemophily and entomophily occur in aquatic plants with emergent flowers).

18. What is the function of the two male gametes produced by each pollen grain in angiosperms?

Ans. Angiosperms perform double fertilization. One male gamete of a pollen grain fuses with the egg to form diploid zygote in generative fertilization. The second male gamete fuses with the central cell to produce triploid primary endosperm cell in vegetative fertilization.

Short Answer Type Questions

1. List three strategies that a bisexual chasmogamous flower can evolve to prevent self pollination.

Ans. (i) **Dichogamy.** Anthers and stigma of the flower mature at different times, anthers first in **protandry** (e.g., *Salvia*) and stigma first in **protogyny** (e.g., *Mirabilis jalapa*).
 (ii) **Self Incompatibility.** Pollen grains of a flower do not germinate over the stigma of the same flower, e.g., Tobacco, Potato.
 (iii) **Heterospory.** Stigma and anthers reach to different heights, e.g., diheterostyly in *Primula*, triheterostyly in *Lythrum*.
 (iv) **Herkogamy.** The flower has mechanical device to prevent self pollination like lever mechanism in *Salvia*.

2. Given below are events that are observed in an artificial hybridisation programme. Arrange them in the correct sequential order in which they are followed in the hybridisation programme— (a) Re-bagging, (b) Selection of parents, (c) Bagging, (d) Dusting the pollen on stigma, (e) Emasculation, (f) Collection of pollen from male parent.

Ans. (b), (e), (c), (f), (d) and (a).

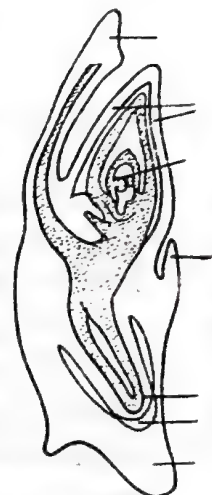
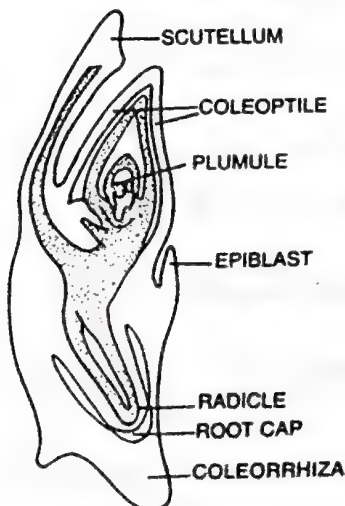
3. Vivipary automatically limits the number of offspring in a litter. Why ?

Ans. Vivipary is nourishment and growth of embryo inside the body of the female till it becomes fully formed and delivered. Vivipary provides protection and assured nourishment to the young ones. As the female has a limited space and nourishment, the number of youngones always kept low, e.g., one in humans and cattle, 6-12 in Rabbit and Rat.

4. Does self incompatibility impose any restriction on autogamy ? Give reasons and suggest the method of pollination in such plants.

Ans. Self incompatibility imposes a bar to autogamy or self pollination. It is due to inability of the pollen to germinate and fertilize the ovule of the same flower. Self incompatible plants perform cross pollination.

5. In the given diagram, write the names of parts shown with lines.



Ans.

6. **What is polyembryony ? How can it be commercially exploited ?**

Ans. Polyembryony is the formation of two or more embryos in the same seed. It occurs naturally in some seeds, e.g., *Citrus*. The phenomenon is controlled by genes. The extra viable embryos formed in a seed generally develop apomictically from diploid cells of nucellus and integument. They can be made to replace the normal embryo. This will be useful in indefinitely retaining the hybrid vigour once introduced in a plant.

7. **Are parthenocarpy and apomixis different phenomena? Discuss.**

Ans. Yes. Parthenocarpy is the formation of seedless fruits while apomixis is formation of embryo from an unfertilized cell within an ovule which grows into seed present in the fruit. **Benefits.** Parthenocarpy is commercially useful in exploitation of fruits as there is no need to remove the seeds. Apomixis has a future if it can be introduced in the hybrid plants for indefinite maintenance of hybrid vigour.

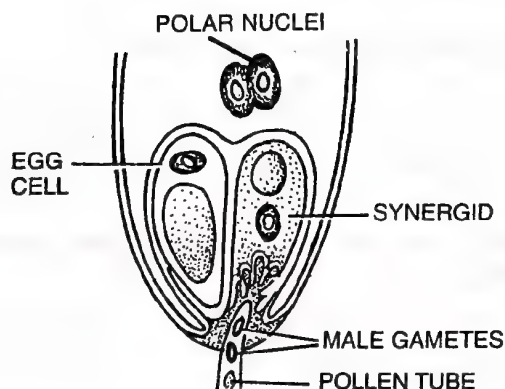
8. **Why does the zygote begin to divide only after the division of primary endosperm cell (PEC)?**

Ans. Primary endosperm cell (PEC) is to form the food laden endosperm for nourishment of developing embryo. Therefore, division of PEC for production of endosperm is a pre-requisite for division of zygote in the formation of embryo.

9. **The generative cell of a two-celled pollen divides in the pollen tube but not in three-celled pollen. Give reasons.**

Ans. In 3-celled pollen, there is one vegetative or tube cell and two male gametes. In two-celled pollen, there is one vegetative cell and a generative cell. Here the generative cell divides in the pollen tube to form two male gametes which are already present in 3-celled pollen. Therefore, there is no need for further division in 3-celled pollen.

10. **In the given figure, label the following parts — male gametes, egg cell, polar nuclei, synergid and pollen tube.**



Long Answer Type Questions

- Starting with the zygote, draw the diagrams of the different stages of embryo development in a dicot.
- What are the possible types of pollinations in chasmogamous flowers. Give reasons.
- With a neat, labelled diagram, describe the parts of a mature angiosperm embryo sac. Mention the role of synergids.
- Draw the diagram of a microsporangium and label its wall layers. Write briefly on the role of the endothecium.
- Embryo sacs of some apomictic species appear normal but contain diploid cells. Suggest a suitable explanation for the condition.

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

Chapter—3

HUMAN REPRODUCTION

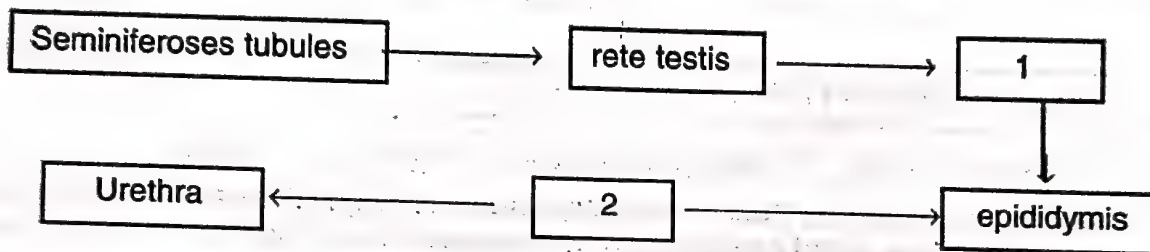
Very Short Answer Type Questions

1. Given below are the events in human reproduction. Write them in correct sequential order.

Insemination, gametogenesis, fertilisation, parturition, gestation, implantation.

Ans. Gametogenesis, insemination, fertilization, implantation, gestation, parturition.

2. The path of sperm transport is given below. Provide the missing steps in blank boxes.



Ans. 1. Vasa efferentia ; 2. Vas deferens

3. What is the role of cervix in the human female reproductive system?

Ans. (i) Regulating the passage of sperms into the uterus.
(ii) It also forms birth canal to facilitate parturition.

4. Why are menstrual cycles absent during pregnancy.

Ans. When pregnancy occurs high levels of progesterone and oestrogens suppress the gonadotropin (e.g., FSH). The latter is required for the development of new follicles. Thus new menstrual cycle cannot be initiated as long as FSH secretion is suppressed.

5. Female reproductive organs and associated functions are given below in column A and B. Fill the blank boxes.

Column A	Column B
Ovaries	Ovulation
Oviduct	a
b	Pregnancy
Vagina	Birth

Ans. (a) Fertilization ; (b) Uterus

6. From where the parturition signals arise— mother or foetus? Mention the main hormone involved in parturition.

Ans. Parturition signals arise from foetus and placenta. Oxytocin is the main hormone involved in parturition.

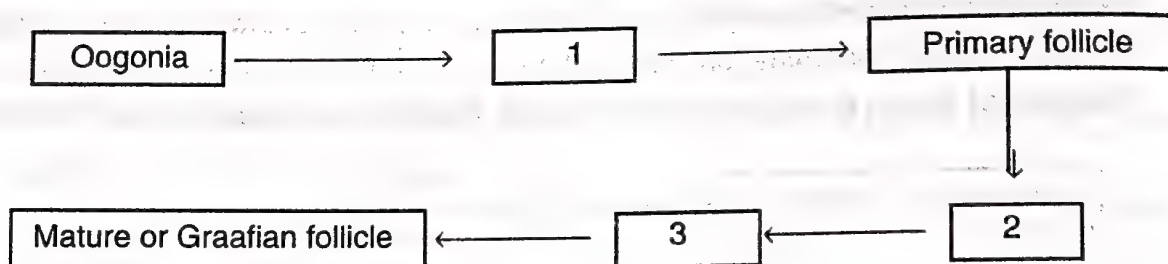
7. What is the significance of epididymis in male fertility?

Ans. (i) Storage and nourishment of spermatozoa required their maturation.
(ii) Rapid movements (peristaltic and segmental) for pushing out sperms at the time of ejaculation.

8. Give the names and functions of the hormones involved in the process of spermatogenesis. Write the names of the endocrine glands from where they are released.

Ans. GnRH (gonadotropin releasing hormone) of hypothalamus acts on anterior pituitary to release gonadotropins, FSH and ICSH. FSH (follicle stimulating hormone) is essential for spermatogenesis, upto the formation of spermatids. ICSH (interstitial cell stimulating hormone) or LH acts on Leydig cells that produce testosterone. Testosterone is essential for spermiogenesis.

9. The mother germ cells are transformed into a mature follicle through series of steps. Provide the missing steps in the blank boxes.



Ans. 1– Primary oocyte ; 2– Secondary follicle ; 3– Secondary oocyte.

10. During reproduction, the chromosome number ($2n$) reduces to half (n) in the gametes and again the original number ($2n$) is restored in the offspring. What are the processes through which these events take place?

Ans. (a) Chromosome number is reduced to half or $1n$ during gametogenesis.
(b) Restoration of chromosome number to diploid or $2n$ stage occurs during fertilization.

11. What is the difference between a primary oocyte and a secondary oocyte?

Primary Oocyte	Secondary Oocyte
1. It is a diploid structure.	1. It is haploid structure.
2. It is formed from oogonium through mitosis and differentiation.	2. It is formed from primary oocyte after it undergoes first meiotic division.
3. No polar body is formed during its development.	3. A polar body is extruded during its formation.

12. What is the significance of ampullary-isthmic junction in the female reproductive tract?

Ans. Ampullary isthmic junction is the place where fertilization of ovum takes place.

13. How does zona pellucida of ovum help in preventing polyspermy?

Ans. After cortical reaction, the chemicals extruded from the fertilized egg destroy the sperm receptors present over zona pellucida. It prevents attachment of another sperm and hence polyspermy.

14. Mention the importance of LH surge during menstrual cycle.

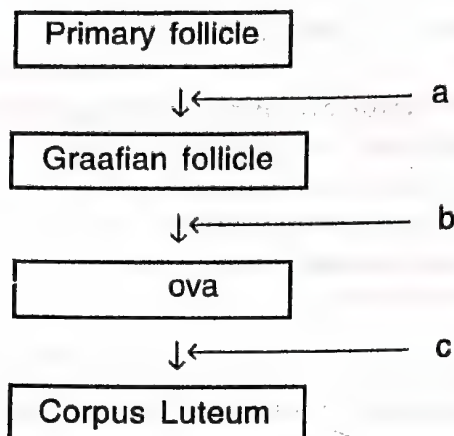
Ans. LH surge causes radial elongation of corona cells, separation of follicular cells from corona cells and **ovulation** or release of ovum from the ovary.

15. Which type of cell division forms spermatids from the secondary spermatocytes?

Ans. Spermatids are formed from secondary spermatocytes through meiosis II that maintains the haploid chromosome number, but helps to separate the chromatids that have become dissimilar due to crossing over.

Short Answer Type Questions

1. **A human female experiences two major changes, menarche and menopause during her life. Mention the significance of both the events.**
 Ans. (a) **Menarche.** It is the first menstruation that occurs in the life of a young girl. Menarche is indication of the attainment of sexual maturity and beginning of fertile period.
 (b) **Menopause.** It is the cessation of menstruation in the life of a woman that marks the end of fertile period due to non-release of ova.
2. (a) **How many spermatozoa are formed from one secondary spermatocyte?**
 (b) **Where does the first cleavage division of zygote take place?**
 Ans. (a) Two (formed by meiosis II).
 (b) **First Cleavage.** It occurs in the oviduct just below the area of fertilization.
3. **Corpus luteum in pregnancy has a long life. However, if fertilisation does not take place, it remains active only for 10-12 days. Explain.**
 Ans. Corpus luteum is retained in response to gonadotropin hormone LH (luteinising hormone). During pregnancy, maternal endometrium is regularly sending neural signals to hypothalamus for inducing anterior pituitary to secrete LH. In the absence of pregnancy, LH secretion decreases resulting in degeneration of corpus luteum.
4. **What is foetal ejection reflex? Explain how it leads to parturition?**
 Ans. Foetal ejection reflex is the origin of signals from the fully formed foetus and placenta. Mild uterine contractions develop. There is a positive feed back or cascade effect. Both mother and foetus secrete oxytocin. Uterine contractions become stronger and stronger. Head of the baby is pushed to cervix which gets dilated and stretched. A similar dilation occurs in vagina. Intensity of uterine and abdominal contractions increases. Amniotic membrane ruptures. Amniotic fluid passes out. Soon it is followed by expulsion of the baby.
5. **Except endocrine function, what are the other functions of placenta.**
 Ans. Placenta is foetomaternal connective that supports the foetus during its development. Its nonendocrine functions are (i) **Nutrition** or supply of nutrients by the mother to the foetus. (ii) **Exchange of Gases.** Through placenta, the mother supplies O_2 to foetus and takes away CO_2 produced by the foetus. (iii) **Excretion.** Foetus eliminates its nitrogenous and other wastes through placenta. (iv) **Antibodies.** Mother's antibodies enter foetal blood through placenta and protect it from several diseases. (v) **Barrier.** Placenta does not allow passage of pathogens and toxins from entering the foetus.
6. **Why doctors recommend breast feeding during initial period of infant growth?**
 Ans. Because (i) Mother's milk is a perfect diet for neonates and young infants. (ii) Mother's milk has antibodies (IgA, IgG) and several biochemicals for providing resistance against several pathogens. (iii) Mother provides phagocytes to the baby for killing germs. (iv) Breast feeding is a natural method for preventing another pregnancy soon after.
7. **What are the events that take place in the ovary and uterus during follicular phase of the menstrual cycle.**
 Ans. (a) **Ovary.** 6–12 ovarian follicles begin growth but only one reaches maturity and forms **Graafian follicle.** The latter secretes oestrogen.
 (b) **Uterus.** Endometrium thickens. There is development of new blood capillaries and proliferation of uterine glands.
 Follicular phase ends in ovulation. It requires high titre of LH.
8. **Given below is a flow chart showing ovarian changes during menstrual cycle. Fill in the spaces giving the name of the hormones responsible for the events shown.**



Ans. a— FSH (follicle stimulating hormone), b—Estrogen and LH, C—LH (luteinising hormone).

9. Give a schematic labelled diagram to represent Oogenesis (without descriptions)

Ans. Draw Figure 3.18 from Elementary Biology. Vol. II.

10. What are the changes in the oogonia during the transition of a primary follicle to Graafian follicle?

Ans. Primary follicle consists of a primary oocyte (in diakinesis stage of meiosis I) surrounded by granulosa cells. Theca develops around the follicle forming secondary follicle. Granulosa cells secrete a fluid and create a cavity called antrum. Antrum containing follicle is called tertiary follicle. Meiosis I is completed. It produces secondary oocyte and a polar body. Follicle grows further and is called Graafian follicle. Zona pellucida develops around secondary oocyte which reaches upto metaphase II stage.

Long Answer Type Questions

1. What role does pituitary gonadotropins play during follicular and ovulatory phases of menstrual cycle? Explain the shifts in steroidal secretions.

Ans. Hints (i) Role of FSH ; (ii) Role of oestrogen ; (iii) Surge of LH causes ovulation; (iv) The empty follicle is converted into corpus luteum by LH ; (v) Corpus luteum secretes progesterone and oestrogen for growth and maintenance of uterine endometrium.

2. Meiotic division during oogenesis is different from that in spermatogenesis. Explain how and why?

Ans. Hint. See the text and figure of oogenesis and spermatogenesis from the book.

3. The zygote passes through several developmental stages till implantation. Describe each stage briefly with suitable diagrams.

Ans. Hints. Describe cleavage, morula, blastocyst (blastula), implantation.

4. Draw a neat diagram of the female reproductive system and label the parts associated with the following (a) production of gamete, (b) site of fertilisation (c) site of implantation and (d) birth canal.

Ans. Hints. Draw Fig. 3.9 (Elementary Biology) (a) ovary-production of gametes; (b) site of fertilization Ampulla-isthmus junction; (c) site of implantation-Endometrium; (d) birth canal, cervical canal and vaginal canal.

5. With a suitable diagram, describe the organisation of mammary gland.

Ans. Draw Fig. 3.14 (Elementary Biology) and describe the organisation of mammary gland.

Chapter—4

REPRODUCTIVE HEALTH

Very Short Answer Type Questions

1. **Reproductive health refers only to healthy reproductive functions. Comment.**
 Ans. Yes. Reproductive health is a state of physical, physiological, psychological, behavioural and social fitness for leading a responsible, safe and satisfying reproductive life.
2. **Comment on the Reproductive and Child Health Care programme of the government to improve the reproductive health of the people.**
 Ans. RCH is reproductive and child health care programme of the government which was launched in 1997. One of its goals is improving reproductive health of the population by providing information and assistance about various aspects of reproduction, reproductive organs, their hygienic care, sexually transmitted diseases (STDs), maternity care, post-natal care, spacing of children for their better upbringing and better health of the mother.
3. **The present population growth rate in India is alarming. Suggest ways to check it.**
 Ans. (i) Spread of education facilities. (ii) Making young people career conscious. (iii) Providing vocational training for gainful employment. (iv) Wider spread of information and materials for birth control.
4. **STDs can be considered as self-invited diseases. Comment.**
 Ans. STDs are self-invited diseases as they occur in persons having unprotected sex with unknown/multiple partners.
5. **Suggest the reproduction-related aspects in which counselling should be provided at the school level.**
 Ans. Counselling should be provided to students about reproduction related problems as (i) Students are experiencing physical, physiological and psychological changes during adolescence. (ii) Students should be guided about harms of early sex, hygiene of reproductive organs and STDs.
6. **Mention the primary aim of the “Assisted Reproductive Technology” (ART) programme.**
 Ans. The primary aim of ART (assisted reproductive technology) is to help infertile couples in having offspring by retrieving oocytes from the ovary or sperms from testis, bringing about artificial insemination and development of embryo.
7. **What is the significance of progesterone-estrogen combination as a contraceptive measure?**
 Ans. It provides hormone level that prevents ovulation and passage of sperms through cervix without affecting feminine traits of the user.
8. **Strict conditions are to be followed in medical termination of pregnancy (MTP) procedures. Mention two reasons.**
 Ans. (i) To check indiscriminate and illegal female foeticides. (ii) Protection from unsafe, dangerous and often fatal MTPs at the hands of unqualified quacks.
9. **Males in whom testes fail to descend to the scrotum are generally infertile. Why?**
 Ans. Testes which fail to descend into scrotum (cryptorchidism) remain in the abdomen where temperature is more than the one required for proper spermatogenesis. As a result, fertile sperms are not produced.

10. **Mention two advantages of lactational amenorrhea as a contraceptive method.**

Ans. Lactational amenorrhoea (LAM) is the phase of absence of menstruation in intensely lactating mothers. It is a natural contraceptive (no pregnancy) period upto six months after parturition. (i) No ovulation and hence no menstrual cycle occurs. (ii) There is no side effect as no medicine or device is used.

Short Answer Type Questions

1. **Suggest some important steps that you would recommend to be taken to improve the reproductive health standards in India.**

Ans. See Elementary Biology NCERT Questions— Answer of question 2.

2. **The procedure of GIFT involves the transfer of female gamete to the fallopian tube. Can gametes be transferred to the uterus to achieve the same result? Explain.**

Ans. No. Fertilisation in uterus is of no consequence as corona radiata and zona pellucida present around the zygote will not allow implantation. The zygote will pass out without undergoing segmentation and blastulation.

3. **Copper ions-releasing IUDs are more efficient than non-medicated methods. Why?**

Ans. Like non-medicated IUDs, they increase phagocytosis of sperms and bring about unsuitable changes in the female genital tract. In addition, they suppress sperm motility so that fertilization of ovum does not occur.

4. **What are the probable factors that contributed to population explosion in India?**

Ans. See Elementary Biology NCERT Questions— Answer of question 5.

5. **Briefly explain IVF and ET. What are the conditions in which these methods are advised?**

Ans. IVF is *in vitro* fertilization. ET is embryo transfer. For *in vitro* fertilization mature ova and active sperms are collected hygienically. Fertilization is performed in glass containers in the laboratory set up under simulated conditions. The zygotes or fertilized eggs are allowed to undergo cleavage in an incubator for 2-3 days. 16-32 celled embryo is transferred to uterine region of the host or surrogate mother during secretory phase. Early embryo (upto 8 celled) is transferred to the fallopian tube.

6. **What are the advantages of natural methods of contraception over artificial methods?**

Ans. Natural methods of contraception include safe period, coitus interruptus and lactational amenorrhoea. Their advantages over artificial methods are as follows :

1. **No Devices.** They do not use any artificial device for preventing conception. There is, therefore, nothing artificial that can cause any discomfort.
2. **No Chemicals.** No chemical or hormone is used. Physiological and biochemical balance is, therefore, not disturbed.
3. **Surgical Procedure.** No surgical procedure or implantation is used. Therefore, there is no psychological problem.
4. **No Religious Sanction.** The method is not opposed by any religion.

7. **What are the conditions in which medical termination of pregnancy is advised ?**

Ans. (1) If pregnancy is likely to produce a congenitally malformed child.
(2) In case of rape.
(3) Contraceptive failure.
(4) Pregnancy is likely to harm the mother.

8. **Comment on the essential features required for an ideal contraceptive.**

Ans. (i) User friendly, *i.e.*, comfortable and easy to use. (ii) Without any side effect. (iii) Reversible. (iv) Completely effective against pregnancy.

9. **All reproductive tract infections RTIs are STDs, but all STDs are not RTIs. Justify with example.**

- Ans.** Reproductive tract infections (RTIs) are transferred from one partner to the other through sex. They are, therefore, STDs or sexually transmitted diseases, *e.g.*, gonorrhoea, syphilis, genital herpes, chlamydiasis. However, there are some STDs which are not infectious of reproductive tract or organs, *e.g.*, Hepatitis-B, AIDS. However, they can be transmitted through sexual contact as their pathogens occur in secretions of reproductive tracts.

Long Answer Type Questions

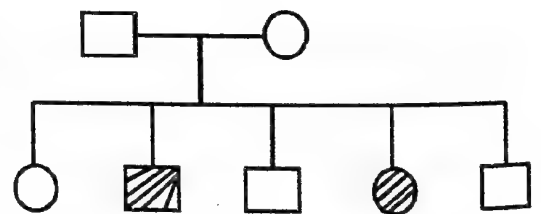
1. **What are the Assisted Reproductive Techniques practised to help infertile couples? Describe any three techniques.**
Ans. Hints. See Elementary Biology under NCERT Question 9 with Answer.
2. **Discuss the mode of action and advantages/disadvantages of hormonal contraceptives.**
Ans. Hints. (i) **Mode of Action.** Oestrogen inhibits ovulation by preventing FSH production.
 (ii) **Advantages.** Hormonal contraceptives are surer devices to prevent conception.
 (iii) **Disadvantages.** They disturb the menstrual cycles.
3. **STDs are a threat to reproductive health. Describe any two such diseases and suggest preventive measures.**
Ans. Hints. (i) Because they cause itching, pain, swelling and fluid discharge from genitalia.
 (ii) The two STDs are (a) **Gonorrhoea**; (b) **Syphilis**
4. **Do you justify the statutory ban on amniocentesis in our country? Give reasons.**
Ans. Hints. See Elementary Biology under NCERT Question 8.
5. **Enumerate and describe any five reasons for introducing sex education to school-going children.**
Ans. Hints. See Elementary Biology under NCERT Question 3.

Chapter—5

PRINCIPLES OF INHERITANCE AND VARIATION

Very Short Answer Type Questions

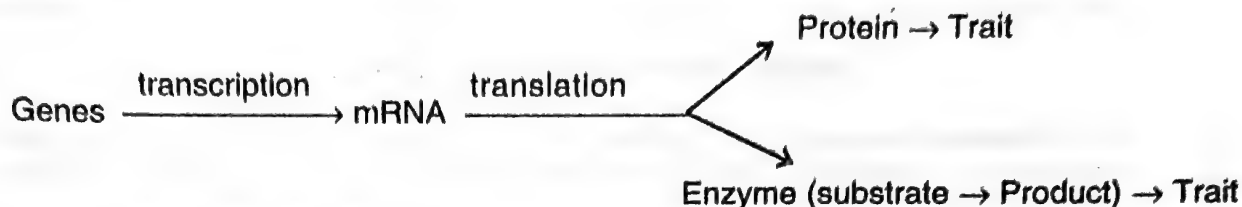
1. **What is the cross between the progeny of F_1 and homozygous recessive parent called? How is it useful?**
Ans. It is called **test cross**. The cross is performed to know the genotype (homozygous or heterozygous) of the individuals with dominant trait.
2. **Do you think Mendel's laws of inheritance would have been different if the characters that he chose were located on the same chromosome?**
Ans. Mendel's laws of dominance and segregation would have remained the same. Occurrence of characters on the same chromosome would have deprived him of the discovery of law of independent assortment.
3. **Enlist the steps of controlled cross pollination. Would emasculation be needed in a cucurbit plant? Give reasons for your answer.**
Ans. (a) Selection of parents; emasculation of flowers of female parent, bagging of flowers, collection of pollen from flowers of male parent, dusting of pollen on the stigmas of female parent, rebagging, collection of fruits and seeds.
 (b) No. F_2 emasculation is not required in cucurbits as they have unisexual flowers. However, bagging is required to prevent contamination.
4. **A person has to perform crosses for the purpose of studying inheritance of a few traits/characters. What should be criteria for selecting the organisms?**
Ans. (i) Availability of pure lines, i.e., pure dominant and pure recessive. (ii) Large progeny but short life span. (iii) Minimum care of the organism. (iv) Easily differentiable traits. (v) Easy mating and self breeding.
5. **The pedigree chart shows a particular trait which is absent in parents but present in the next generation irrespective of sexes. Draw your conclusion on the basis of the pedigree.**
Ans. Since the parents do not show the trait, they must be carrier of its recessive allele. As the trait appears in siblings of both the sexes, it is present on an autosome. Therefore, the trait shown in the pedigree chart is an autosomal recessive carried by both the parents (Pp, Pp). It appears in some children (pp). Other children are either carrier (Pp) or free from the allele (PP).
6. **In order to obtain the F_1 generation, Mendel pollinated a pure breeding tall plant with a pure breeding dwarf plant. But for getting the F_2 generation, he simply self pollinated the tall F_1 plants. Why?**
Ans. Mendel cross pollinated plants of two different traits of the character of height in order to study their mixing in F_1 generation. Only one trait appeared in F_1 plants. What is the fate of the other trait? For solving the riddle, he allowed F_1 plants to self pollinate. F_2 generation



showed both the traits indicating that the recessive trait of dwarfness remains in F_1 generation but without expression.

7. **"Genes contain the information that is required to express a particular trait". Explain.**

Ans. Genes contain information for forming particular biochemicals like proteins, hormones, enzymes, etc. These biochemicals help in producing the trait. The process of gene expression involves central dogma of genetics, e.g., transcription and translation.



8. **How are alleles of particular gene differ from each other? Explain its significance.**

Ans. Alleles of a gene differ from one another in some nucleotides due to mutational changes. As a result, they produce different traits. Occurrence of different alleles of a gene produces variability in the organisms.

9. **In a monohybrid cross of plants with red and white flowered plants, Mendel got only red flowered plants. On self pollinating these F_1 plants, he got both red and white flowered plants in 3 : 1 ratio. Explain the basis of using RR and rr symbols to represent the genotypes of plants of parental generation.**

Ans. Occurrence of both red and white flowered plants after selfing of red flowered F_1 plants indicates that the latter have factors of both the traits (red and white) but the factor for white flower colour is recessive and does not express its effect in the presence of factor for red colour. It expresses its effect only when it is in a pair itself. Therefore, Mendel presumed correctly that each character is represented by two factors. The parents of the present cross, being pure, carry the factors RR (red flower) and rr (white flower).

10. **For the expression of traits genes provide only the potentiality and environment provides the opportunity. Comment on the veracity of the statement.**

Ans. Expression of a trait (phenotype) depends upon two things, the product of gene (potentiality) and environmental inputs (opportunity). The environmental inputs provide materials for gene product to show its effect. A genetically tall Pea plant can become tall only if it receives proper amount of minerals, water and sunlight.

Phenotype (Trait) = Genotype (Potentiality) + Environment (Opportunity)

11. **A, B, D are three independently assorting genes with their recessive alleles a, b, d respectively. A cross was made between individuals of AabbDD genotype with aabbdd. Find out the type of genotypes of the offspring produced.**

Ans. Genotype aabbdd produces only one type of gametes abd. Genotype Aa bb DD forms two types of gametes AbD and abD. Genotypes of offspring will be

	AbD	abD	
abd	Aa bb Dd	aa bb Dd	Aa bb Dd and aa bb Dd

12. **In our society a woman is often blamed for not bearing male child. Do you think it is right? Justify.**

Ans. Women have no genetic or otherwise role in the sex of the child. They are homogametic and produce only one type of ova (A + X). Males are heterogametic. They produce two types of sperms, A + X (gynosperms) and A + Y (androsperms). It is the type of sperm that fertilizes the ovum which determines the sex of the child.

13. **Discuss the genetic basis of wrinkled phenotype of Pea seed.**

Ans. Pea plants having wrinkled seeds possess a pair of recessive alleles (bb) that gives rise to small-sized starch grains.

14. **Even if a character shows multiple allelism, an individual will only have two alleles for that character. Why?**

Ans. A chromosome carries only one allele of a character. An individual which is diploid can have only two chromosomes of each type and hence only two alleles despite the occurrence of several alleles in the population.

15. How does a mutagen induce mutation? Explain with example.

Ans. A mutagen changes nucleotide sequence of a gene by either deletion or addition of nucleotides (e.g., acridines), functioning as base analogues (e.g., 5-bromouracil, 5-fluorouracil), alkylating (e.g., nitrogen mustard) and deaminating (e.g., nitrous acid) agents.

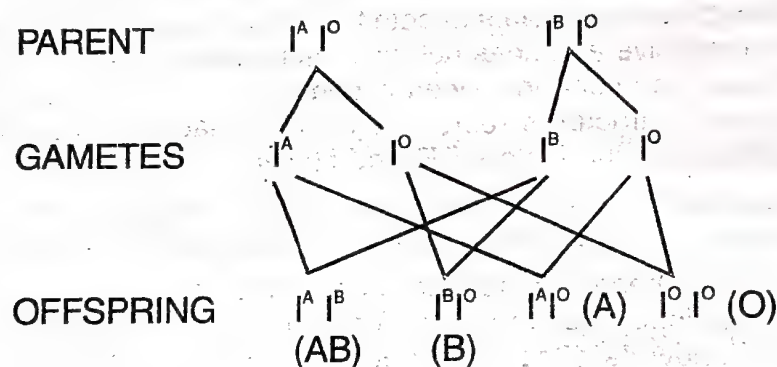
Short Answer Type Questions

1. In a Mendelian monohybrid cross, the F_2 generation shows identical genotypic and phenotypic ratios. What does it tell us about the nature of alleles involved? Justify your answer.

Ans. In the common monohybrid cross F_2 generation shows a phenotypic ratio of 3 : 1 and genotypic ratio of 1 : 2 : 1. Same phenotypic and genotypic ratios of 1 : 2 : 1 occur in case of **incomplete dominance**. In a cross between red flowered four O' clock (RR) with white flowered Four O' clock (rr), F_1 plants are pink flowered (Rr). Self pollination of these hybrids yield similar phenotypic and genotypic ratio of 1 red flowered : 2 pink flowered : 1 white flowered plants. Draw Fig. 5.6 from Elementary Biology.

2. Can a child have blood group O if his parents have blood group 'A' and 'B'. Explain.

Ans. Yes, if the parents are heterozygous for their blood groups.



3. What is Down's syndrome? Give its symptoms and cause. Why is it that the chances of having a child with Down's syndrome increases if the age of the mother exceeds forty years.

Ans. The syndrome is characterised by rounded face, broad fore-head, permanently open mouth, broad palm with palmer crease, furrowed tongue, projecting lower lip and protruding tongue and mongolian type eye fold or **epicanthus**. IQ is low and many internal organs are defective.

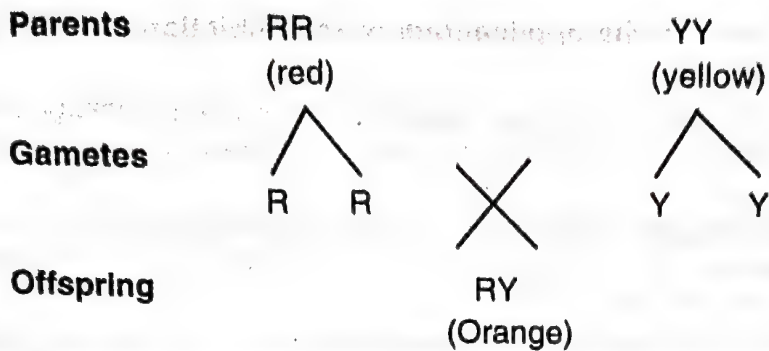
Down's syndrome is caused by **trisomy** of chromosome 21. It is often due to nondisjunction of chromosome pair 21 during oogenesis. The chances of this nondisjunction increases if the age of the mother exceeds 40 _____ 1/2000 below 30, 1/900 at 30, 1/400 at 40 at 1/40 at 45 years.

4. How was it concluded that genes are located on chromosomes?

Ans. Occurrence of genes over chromosomes was proved by Morgan (1910) during study of sex-linked inheritance of eye colour in *Drosophila*. It shows criss-cross inheritance. The female fly passes its X-chromosome and hence eye colour trait to male offspring, while male fly passes its X-chromosome and hence eye colour to the female offspring.

5. A plant with red flowers was crossed with another plant with yellow flowers. If F_1 showed all flowers orange in colour, explain the inheritance.

Ans. It is a case of **incomplete dominance**. The trait of yellow colour is not recessive. It dilutes the trait of red colour and produces orange coloured flowers.



6. What are the characteristic features of a true breeding line?

Ans. A true breeding line is **pure line** (Johannsen 1900) which shows the same traits generation after generation due to their occurrence in homozygous state. Pure or true breeding lines are produced through repeated self fertilization or breeding between identical homozygous ancestors. They are not superior to high yielding varieties but are maintained for cross breeding and formation of new varieties.

7. In peas, tallness is dominant over dwarfness and red colour of flowers is dominant over the white colour. When a tall plant bearing red flowers was pollinated with dwarf plant bearing white flowers, the different phenotypic groups were obtained in the progeny in number (a) Tall, red — 138 (b) Tall, white — 132 (c) Dwarf, red — 136 and (d) Dwarf, white — 128. Mention the genotypes of the two parents and of the four offspring types.

Ans. The result shows that the four types of offspring occur in nearly the same number so that the ratio comes to 1 : 1 : 1 : 1. This ratio appears in case of dihybrid test cross. One parent is double recessive (dwarf and white $tt\ rr$) while the second parent is double hybrid (tall and red, $TtRr$). The double hybrid will give four types of gametes (TR , Tr , tR , tr) while the double recessive will produce only one type of gametes (tr). The test cross is

	TR	Tr	tR	tr
tr	$TtRr$	$Ttrr$	$ttRr$	$ttrr$

The genotypes of the offspring are, therefore, $TtRr$ (tall red), $Ttrr$ (tall white), $ttRr$ (dwarf red) and $ttrr$ (dwarf white).

8. Why is the frequency of red green colour blindness is many times higher in males than in the females?

Ans. Red-green colour blindness is due to X-linked recessive allele. Males are hemizygous for this chromosome. A single recessive allele will express its effect in them. Females have two or XX chromosomes. They can become colour blind only when both their X-chromosomes carry the recessive trait. This is however, very rare due to large scale heterozygosity in human population.

9. If a father and son are both defective in red-green colour vision, is it likely that the son inherited the trait from his father? Comment.

Ans. Red-green colour blindness is X-linked recessive trait. Males are hemizygous for X-chromosome. They receive it from their mother and not father (criss-cross inheritance). If son is colour blind, he must have received the trait from his mother who is carrier of the defect (heterozygous) but is not suffering from the disease.

10. Discuss why *Drosophila* has been used extensively for genetical studies.

Ans. See text Elementary Biology Page U2–24 points (i) to (viii)

11. How do genes and chromosomes share similarity from the point of view of genetical studies.

Ans. (i) Both pass from generation to generation in unaltered form. (ii) They occur singly in gametes. (iii) An individual receives two genes and two chromosomes of each type from its two parents. (iv) Each gene and each chromosome replicates during S-phase of cell cycle. (v) They follow mendelian principles.

12. What is recombination? Discuss the applications of recombination from the point of view of genetic engineering.

Ans. Recombination is new combination or linking of genes to form altered linkages. It occurs naturally through crossing over and coming together of different chromosomes during fertilization.

Recombinations indicate the position of genes. In genetic engineering, the desired genes can be taken from one source and introduce them in the cells of another organism in order to improve and change the same.

13. What is artificial selection? Do you think it affects the process of natural selection? How?

Ans. Artificial selection is breeding plants and animals so as to introduce and enhance specific traits in large number of individuals. Several breeds of dogs, horses, pigeons, cattle, vegetables, etc have been produced by human beings through artificial selection.

Artificial selection does affect natural selection. Natural selection is based on appearance of variations, competence and adaptations to changes in the environment. Artificial selection gives artificial environment to selected plants and animals, eliminating competition, environmental adaptation and hence natural selection.

14. With the help of an example, differentiate between incomplete dominance and co-dominance.

Ans. See text of Elementary Biology — Page U2-18 for differences. **Examples—** (i) In complete dominance— flower colour in four O' clock. (ii) Codominance — A and B blood groups.

15. It is said that harmful alleles get eliminated from population over a period of time. Yet sickle cell anaemia is persisting in human population. Why?

Ans. Harmful alleles become lethal whenever they occur in homozygous state. The affected individual, therefore, does not transfer them to the next generation. Over a period of time, such alleles are eliminated from the population. This is not so in case of sickle cell anaemia. Here, the heterozygous condition ($Hb^A Hb^S$) despite being uncomfortable is useful in malaria affected areas. The malaria parasite is unable to enter the RBCs of $Hb^A Hb^S$ individuals. Being helpful, the allele for sickle cell anaemia continues to persist.

Long Answer Type Questions

1. In a plant tallness is dominant over dwarfness and red flower is dominant over white. Starting with the parents work out a dihybrid cross. What is standard dihybrid ratio? Do you think the values would deviate if the two genes in question are interacting with each other?

2. a. In humans, males are heterogametic and females are homogametic. Explain. Are there any examples where males are homogametic and females heterogametic?

b. Also describe as to, who determines the sex of an unborn child? Mention whether temperature has a role in sex determination.

3. A normal visioned woman, whose father is colour blind, marries a normal visioned man. What would be probability of her sons and daughters to be colour blind? Explain with the help of a pedigree chart.

4. Discuss in detail the contributions of Morgan and Sturvant in the area of genetics.

5. Define aneuploidy. How is it different from polyploidy? Describe the individuals having following chromosomal abnormalities.

a. Trisomy of 21st Chromosome

b. XXY

c. XO

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

Chapter—6

MOLECULAR BASIS OF INHERITANCE

Very Short Answer Type Questions

1. **What is the function of histones in DNA packaging?**
 Ans. Histones form nucleosome cores and linker molecules in DNA packaging. They expose their positively charged ends over their surface to attract negatively charged DNA (due to phosphate ions) for its wrapping and coiling.
2. **Distinguish between heterochromatin and euchromatin. Which of the two is transcriptionally active?**
 Ans. Heterochromatin is thicker, tightly packed and darkly stained part of chromatin while euchromatin is thinner, loosely packed and lightly stained part of chromatin. Transcriptionally active part is euchromatin.
3. **The enzyme DNA polymerase in *E. coli* is a DNA dependent polymerase which has also the ability to proof-read the DNA strand being synthesised. Explain. Discuss the dual polymerase.**
 Ans. DNA polymerase can recognise the complementary nucleotides for exposed nitrogen bases of the template strands. It also builds phosphodiester bonds between adjacent nucleotides. Any wrong nucleotide entering the new strand is removed by it and replaced by the correct one. This is called proof reading. DNA polymerase, therefore, helps in building new DNA strands as well as proof-read the same.
4. **What is the cause of discontinuous synthesis of DNA on one of the parental strands of DNA? What happens to these short stretches of synthesised DNA?**
 Ans. New DNA is formed in only 5' → 3' direction over the DNA template with 3' → 5' orientation. However, when DNA opens for replication, one of the strand has 3' → 5' orientation while the other has 5' → 3' orientation. The 3' → 5' strand forms a continuous new strand over it. It is called leading strand. The other template with 5' → 3' orientation produce a new short strand over the fork end towards the free end. Every time, the fork opens, a new short strand is formed over it. These short strands are called **Okazaki fragments**. They are joined by DNA ligase to form lagging strand.
5. **Given below is the sequence of coding strand of DNA in a transcription unit 3' — AATGCAGCTATT AGG — 5'. Write the sequence of its (a) Complementary strand (b) mRNA.**
 Ans. (a) Complementary strand = 5' — TTACGTCGATAATCC — 3'.
 (b) mRNA = 5' — AAUGCAGCUAUUAGG — 3'
6. **What is DNA polymorphism? Why is it important to study it?**
 Ans. DNA polymorphism is the occurrence of variations in the structure of DNA due to presence of different number and forms of noncoding sequences like single nucleotides, minisatellites, microsatellites, restriction fragment lengths, etc. DNA polymorphism is the basis of genetic mapping of human genome, origin and migration of human tribes and DNA finger printing used in identification of relations and animals.
7. **Based on your understanding of genetic code, explain the formation of any abnormal haemoglobin molecule. What are the known consequences of such a change?**

Ans. Change in nucleotide type and sequence results in formation of changed haemoglobin, e.g., thalassemia, sickle cell anaemia. A single codon mutation from GAG to GUG at sixth position of haemoglobin- β chain gene changes amino acid, glutamic acid to valine. Valine builds hydrophobic bonds under condition of oxygen stress. This causes distortion of haemoglobin structure that is lethal in homozygous state and produces sickle cell anaemia in heterozygous condition.

8. Sometimes cattle or even human beings give birth to their young ones that are having extremely different sets of organs like limbs/position of eye(s), etc. Comment.

Ans. Development of organs is regulated by expression of different sets of genes in a sequential and highly coordinated manner. Any disturbance in this coordination and regulation produces organs in different positions.

9. In a nucleus, the number of ribonucleoside triphosphates is ten times the number of deoxyribonucleoside triphosphates, but only deoxyribonucleosides are added during DNA replication. Suggest a mechanism.

Ans. The enzyme involved in DNA replication, i.e., DNA polymerase, recognises only deoxyribonucleoside triphosphates. It incorporates the same and not ribonucleosides triphosphates.

10. Name a few enzymes involved in DNA replication other than DNA polymerase and ligase. Name the key function of each of them.

Ans. (i) **Helicase.** Opens the DNA double helix.
(ii) **Topoisomerase.** Corrects supercoiling of DNA strands.
(iii) **Primase.** Formation of RNA primer.
(iv) **Telomerase.** Formation of telomeric end of chromosomes.

11. Name any three viruses which have RNA as genetic material.

Ans. (i) Rous Sarcoma Virus ; (ii) Human immunodeficiency virus or HIV ; (iii) Tobacco mosaic virus.

Short Answer Type Questions

1. Define transformation in Griffith's experiment. Discuss how it helps in the identification of DNA as the genetic material.

Ans. Transformation is a genetic change due to incorporation of genes from outside source. In Griffith's experiment the live nonvirulent pneumonia bacteria became virulent by picking up the factor of virulence from their dead relatives. The transforming material was found out to be DNA by Avery *et al* (1944).

2. Who revealed biochemical nature of transforming principle? How was it done?

Ans. The biochemical nature of transforming principle was discovered by Avery *et al* (1944). They incubated nonvirulent pneumonia bacteria (*Streptococcus pneumoniae*) with carbohydrate, protein, DNA and DNA+ DNAase (nucleotides only) of virulent bacteria in different cultures. Some bacteria of the culture having DNA of virulent form became virulent indicating that the bacteria have picked up the gene from the culture medium which is made of DNA.

3. Discuss the significance of heavy isotope of nitrogen in Meselson and Stahl's experiment.

Ans. Heavy isotope of nitrogen ^{15}N gets incorporated in DNA of bacteria (*E. coli*) and makes it heavy. Change of nitrogen to normal ^{14}N form would naturally cause changes in heaviness of DNA. This was studied by Meselson and Stahl (1958) with the help of density gradient centrifugation in caesium chloride. They found that switch over to ^{14}N (from ^{15}N) produced DNA of intermediate heaviness ($^{15}\text{N } ^{14}\text{N}$) in first generation. In the second generation, DNAs of bacteria were of two types, intermediate heaviness ($^{15}\text{N } ^{14}\text{N}$) and light ($^{14}\text{N } ^{14}\text{N}$). This proved semi conservative nature of DNA replication where one parent strand is retained by the daughter while the second strand is formed anew.

4. Define cistron. Giving examples differentiate between monocistronic and polycistronic transcription unit.

Ans. Cistron is a unit of DNA that specifies a structural gene (Benzer 1955). Transcription unit is a segment of DNA having a promoter region, one or more structural genes and a terminator region. It is **monocistronic** if it has a single structural gene (e.g., eye colour in *Drosophila*) and **polycistronic** if it possesses two or more structural genes (e.g., lac operon of *E. coli*).

5. Give any six features of the human genome.

Ans. (i) Human genome has 3.1647 billion nucleotide pairs. (ii) There are some 30,000 genes. (iii) Maximum number of genes (2968) occur over chromosome 1 and minimum of genes (231) are found over Y-chromosome. (iv) Less than 2% of genome contains structural genes. (v) 99.9% of genome is similar in all humans. (vi) Large portion of human genome is occupied by noncoding repeated sequences and junk DNA.

6. During DNA replication, why is that the entire molecule does not open in one go? Explain replication fork. What are the two functions that the monomass (dNTPs) play?

Ans. DNA is a long molecule. Replication requires perfect accuracy and high energy. Moreover, the replication of the two strands is different. Therefore, DNA replication occurs in short stretches. The stretch of DNA that opens for replication forms a Y-shaped configuration called **replication fork**.

Functions of dNTPs. (i) They provide nucleotides for building of new DNA strand. (ii) They release energy for building bonds (phosphodiester, hydrogen bonds).

7. Retroviruses do not follow central dogma. Comment.

Ans. Retroviruses (e.g., HIV) are RNA viruses. Their genetic material does not directly function as mRNA. They first build complementary DNA through reverse transcription. It is opposite to central dogma. Hence, retroviruses do not follow central dogma in the first instance.

8. In an experiment, DNA is treated with a compound which tends to place itself amongst the stacks of nitrogenous base pairs. As a result of this, the distance between two consecutive base pairs increases from 0.34 nm to 0.44 nm. Calculate the length of DNA double helix (which has 2×10^9 bp) in the presence of saturating amount of this compound.

Ans. $2 \times 10^9 \times 0.44 \text{ nm} = 0.88 \times 10^9 \text{ nm}$

Since 1m is equal to 10^9 , $0.88 \times 10^9 \text{ nm} = 0.88 \text{ m}$.

9. What would happen if histones were to be mutated and made rich in acidic amino acids such as aspartic acid and glutamic acid in place of basic amino acids of lysine and arginine?

Ans. Acidic amino acids are negatively charged like DNA. Histones rich in acidic amino acids will not be able to hold DNA over them. As there will be no packaging of DNA, no chromatin will be formed.

10. Recall the experiments done by Frederick Griffith, Avery, MacLeod and McCarty where DNA was speculated to be the genetic material. If RNA instead of DNA was the genetic material, will the heat killed strain of *Pneumococcus* have transformed the R-strain into virulent strain? Explain.

Ans. RNA is not as thermostable as DNA due to presence of 2' OH group in its ribose. Therefore, it can degrade during heat killing of virulent strain bacteria. Then there will be little chance of transformation of R-strain bacteria if RNA was its genetic material.

11. You are repeating the Hershey-Chase experiment and are provided with two isotopes, ^{32}P and ^{15}N (in place of ^{35}S in the original experiment). How do you expect your results to be different?

Ans. ^{32}P is radioactive. It gets incorporated into DNA. ^{15}N is heavier isotope of nitrogen and not radioactive. Even if it can be detected, ^{15}N will not be able to differentiate genetic material (DNA) from capsid (a protein) as it is incorporated both in DNA (in nitrogen bases) and protein (in amino acids). The experiment will fail.

12. There is only one possible sequence of amino acids when deduced from a given nucleotide sequence. But multiple nucleotides sequence can be deduced from a single amino acid sequence. Explain this phenomenon.

Ans. A nucleotide triplet or codon specifies only one particular amino acid but one amino acid can be specified by more than one codon due to degeneracy of genetic code. For example, AUG – AUU codes for dipeptide Met-Ile but Met-Ile can be specified by three nucleotide sequences— (i) AUG– AUU; (ii) AUG – AUC; (iii) AUG – AUA.

13. A single base mutation in a gene may not 'always' result in loss or gain of function. Do you think the statement is correct? Define your answer.

Ans. It is correct. The degeneracy of codon at wobble or third position is very common. GGA can be replaced by GGU, GGC and GGG without affecting the incorporation of amino acid glycine. Such mutations which do not change the phenotype are called **Silent mutations**.

14. A low level of expression of lac operon occurs at all the time. Can you explain the logic behind this phenomenon.

Ans. Small quantity of permease enzyme of lac operon has to be present if lactose is to enter the cell and act as inducer of the operon. Therefore, a low level of expression of lac operon occurs all the time.

15. How has the sequencing of human genome opened new windows for treatment of various genetic disorders. Discuss amongst your classmates.

Ans. Discuss points 1, 2 and 3 of Elementary Biology Page U2–160.

16. The total number of genes in humans is far less (< 25000) than the previous estimate (upto 1,40,000 genes). Comment.

Ans. The estimate of total number of human genes was very high (about 1,40,000 genes) because of the large size of the human genome. However, most of human genome is made of noncoding repetitive sequences and single nucleotides. Only 2% of the genome actually consists of structural genes which are now estimated to be <25000. Some of them are believed to form more than one type of proteins due to alternate splicing.

17. Now, sequencing of total genome is getting less expensive day by day. Soon it may be affordable for a common man to get his genome sequenced. What in your opinion could be advantage and disadvantage of this development?

Ans. **Advantages.** 1. It will provide information about the number of defective genes. 2. One can know the possibility of transfer of certain genes to the progeny. 3. Ability to resist certain diseases is known. 4. Proneness to certain diseases will make one avoid the factors causing those diseases. 5. It will give information as to timing of normal appearance of degenerative diseases and how to postpone them. 6. Metabolic defects can be taken care of.

Disadvantages. (i) Prior knowledge of proneness to certain diseases will make oneself a worried lot. (ii) Many marriages will breakdown for fear of passage of defects to the offspring. (iii) Persons with good resistance will become careless.

18. Would it be appropriate to use DNA probes such as VNTR in DNA finger printing of a bacteriophage?

Ans. Bacteriophages have small genomes which do not have noncoding repetitive sequences like VNTRs. Therefore, use of VNTR probes for DNA finger printing of a bacteriophage is useless.

19. During *in vitro* synthesis of DNA, a researcher used 2', 3'-di-deoxycytidine triphosphate as raw material in place of 2'-deoxycytidine triphosphate. What would be the consequence.

Ans. 2', 3'-dideoxycytidine phosphate cannot form ester bond required for chain formation of DNA while 2'-deoxycytidine phosphate develops such a bond. Therefore, chain formation of DNA stops wherever 2', 3'-dideoxycytidine triphosphate occurs.

20. What background information did Watson and Crick had with them for developing a model of DNA? What was their own contribution?

Ans. Background Information. (i) DNA is polynucleotide. (ii) Width of DNA is 20\AA . (iii) Distance between adjacent nucleotides is 3.4\AA . (iv) Chargaff's rules indicating number of deoxyribose = phosphate, $A = T$ and $C = G$. (v) DNA is helical structure with each coil having 10 nucleotides.

Contribution of Watson and Crick. (i) DNA is a double helix with the two chains running in antiparallel direction. (ii) Pairing of complementary bases. (iii) Semiconservative replication. (iv) Mutations occur due to tautomeric changes in nitrogen bases.

21. What are the functions of (i) methylated guanosine cap (ii) Poly-A tail in a mature mRNA?

Ans. Methylated Guanosine Cap. It helps in attachment of mRNA to small subunit of ribosome. **Poly-A Tail.** It provides protection to mRNA so that the latter has sufficient longevity for translation work. Length of poly-A tail and longevity of mRNA are positively correlated.

22. Do you think that the alternate splicing of exons may enable a structural gene to code for several isoproteins from one and the same gene? If yes, how? If not, why so?

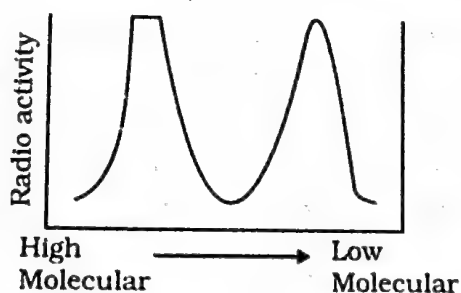
Ans. Yes. Alternate splicing is a mechanism to produce several types of similar mRNAs from a single gene, each of which produces a distinct protein of similar class or isoprotein. The mechanism helps in providing proteins specific to tissues, sexes and development stages.

23. Comment on the utility of variability in number of tandem repeats during DNA finger printing.

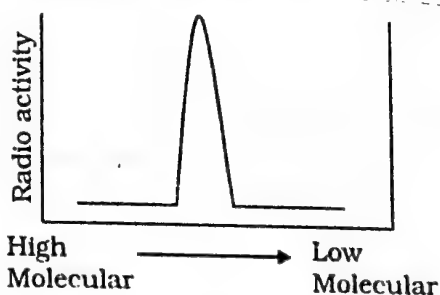
Ans. Number and type of tandem repeats are specific for each individual. Tandem repeats of an individual come from two parents of an individual. Therefore, they can be used to identify the individuals as well their relatives by comparing the repeats through DNA finger printing.

Long Answer Type Questions

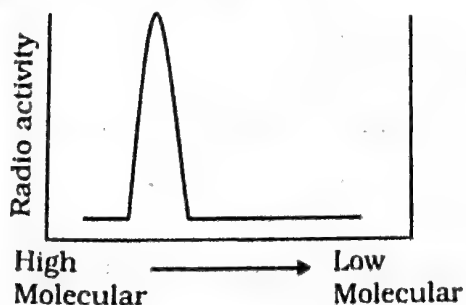
- Give an account of Hershey and Chase experiment. What did it conclusively prove? If both DNA and proteins contained phosphorus and sulphur do you think the result would have been the same?
- Replication was allowed to take place in the presence of radioactive deoxynucleotides precursors in *E.coli* that was a mutant for DNA ligase. Newly synthesised radioactive DNA was purified and strands were separated by denaturation. These were centrifuged using density gradient centrifugation. Which of the following would be a correct result?



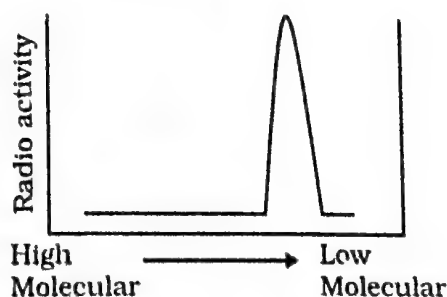
(a)



(b)



(c)



(d)

3. During the course of evolution why DNA was chosen over RNA as genetic material? Give reasons by first discussing the desired criteria in a molecule that can act as genetic material and in the light of biochemical differences between DNA and RNA.
4. Give an account of post transcriptional modifications of a eukaryotic mRNA.
5. Discuss the process of translation in detail.
6. Define an operon. giving an example, explain an Inducible operon.
7. 'There is a paternity dispute for a child'. Which technique can solve the problem. Discuss the principle involved.
8. Give an account of the methods used in sequencing the human genome.
9. List the various markers that are used in DNA finger printing.

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

Chapter—7

EVOLUTION

Very Short Answer Type Questions

1. **What were the characteristic of life forms that had been fossilised?**
Ans. Life forms with hard parts were fossilised.
2. **Did aquatic life forms get fossilised. If yes, where do we come across such fossils.**
Ans. Yes. Aquatic forms have better chance to get fossilised at the bottom of water bodies and become part of sedimentary rocks. Due to upheavals in the crust of earth, these rocks come to the surface and the fossils get exposed.
3. **What are we referring to when we say simple organisms or complex organisms?**
Ans. Simple organisms have simple morphology, anatomy and physiology. Complex organisms have complex morphology, anatomy and complex functional organisation.
4. **How do we compute the age of living tree?**
Ans. (i) By carbon dating (ii) By counting growth rings with the help of increment borer.
5. **Give an example of convergent evolution and identify the features towards which they are converging.**
Ans. Evolution of aquatic mammals and aquatic reptiles is an example of convergent evolution. They all are adapted to aquatic mode of life.
6. **How do we compute the age of a fossil?**
Ans. (i) Age of recent fossils is computed by using radioactive carbon dating method. (ii) Age of very old fossils is determined by radioactive uranium method.
7. **How do we compute the age of a rock?**
Ans. By Uranium-Lead or Potassium-Argon transformations.
8. **When we talk of functional macromolecules (e.g., proteins as enzymes, hormones, receptor antibodies, etc), towards what are they evolving?**
Ans. Macromolecules used in basic metabolic activities remain unchanged in diverse groups of organisms such as enzymes of krebs cycle or enzyme involved in photosynthesis.
9. **In a certain population, the frequency of three genotypes is as follows**

Genotypes	BB	Bb	bb
Frequency	22%	62%	16%

What is the likely frequency of B and b alleles?

Ans. (a) **Frequency of B Allele.** All BB alleles + 50% of Bb

$$= 22 + \frac{1}{2} \times 62$$

$$= 22 + 31 = 53\%$$

(b) **Frequency of b Allele.** All bb alleles + 50% of Bb

$$= 16 + \frac{1}{2} \times 62$$

$$= 16 + 31 = 47$$
10. **Who among the Dryopithecous and Ramapithecus was more man-like?**
Ans. Ramapithecus

11. By what latin name was the first hominid known?
 Ans. *Homo habilis*
12. Among Ramapithecus, Australopithecus and Homo habilis, who probably did not eat meat?
 Ans. *Homo habilis*

Short Answer Type Questions

1. Louis Pasteur's experiments, if you recall, proved that life can arise from only pre-existing life. Can we correct this as life evolves from pre-existent life or otherwise we will never answer the question as to how the first forms of life arose? Comment.
 Ans. Yes, we will have to modify Louis Pasteur's statement that life can arise from only pre-existing life because life cannot arise spontaneously under conditions that exist on earth today. The first form of life appeared as simple self duplicating particles and might have arisen spontaneously from chemical in animate substances.
2. The scientists believe that evolution is gradual. But extinction, part of evolutionary story, are 'sudden' and 'abrupt' and also group-specific. Comment whether a natural disaster can be the cause of extinction of species.
 Ans. Yes, natural disasters that occur on earth from time to time can be cause for mass extinction of species in addition to other factors.
3. Why is nascent oxygen toxic to aerobic life forms?
 Ans. Nascent oxygen, [O], is highly reactive. It can react and oxidise all types of biomolecules, including DNA, proteins, enzymes, etc. present in the cells of aerobic life forms. As a result the metabolic and structural machinery of aerobes will undergo disruption.
4. While creation and presence of variation is directionless, natural selection is directional as it is in the context of adaptation. Comment.
 Ans. All sorts of variations develop randomly in organisms due to random separation of chromosomes and crossing over during gametogenesis, fusion of gametes and appearance of mutations. Only some of them have adaptive value. Nature selects only these variations providing them a proper direction so that individuals become more and more fit in terms of survival.
5. The evolutionary story of moths in England during industrialisation reveals that evolution is apparently reversible. Clarify this statement.
 Ans. The occurrence of industrial melanism is closely associated with the progress of the industrial revolution in Great Britain, during the nineteenth century. **Peppered moth** (*Biston betularia*) is the most intensely studied. Industrial melanism can be written briefly as follows. (i) The peppered moth existed in two strains (forms) : light coloured (white) and melanic (black). (ii) In the past, bark of trees was covered by whitish lichens, so white moths escaped unnoticed from predatory birds. (iii) After industrialisation barks got covered by smoke, so the white moths were selectively picked up by birds. (iv) But black moths escaped unnoticed so they managed to survive resulting in more population of black moths and less population of white moths. Thus *industrial melanism supports evolution by natural selection*.
6. State and explain any three factors affecting allele frequency in populations.
 Ans.
 1. **Gene Flow (Gene Migration).** The movement of individuals from one place to another is called migration. If the migrating individuals breed within the new population, the immigrants will add new alleles to the local gene pool of the host population. This is called **gene migration**.
 2. **Genetic Drift.** Genetic drift is drastic change in allele frequency when the population size becomes very small. Therefore, it alters the gene frequency of remaining population which causes variation. It is named after the American geneticist Sewall Wright who realised its evolutionary significance. Although genetic drift occurs in all populations, its effects are most marked in very small isolated population. Two important examples of genetic drift are founder effect and bottleneck effect.

3. Natural Selection. This is the most widely accepted theory resulting from the **differential reproduction** (some members of a population produce abundant offspring, some only a few and still others none), one phenotype as compared with other phenotypes in the same population. This determines the relative share of different genotypes which individuals possess and propagate in a population.

Long Answer Type Questions

1. **Name the law that states that the sum of allelic frequencies in a population remains constant. What are the five factors that influence these values?**
 Ans. **Hint.** (a) **Hardy-Weinberg law or principle.** (b) **Factors.** Mutations, gene flow, recombinations, genetic drift and natural selection.
2. **Explain divergent evolution in detail. What is the driving force behind it?**
 Ans. (a) *See text under Adaptive Radiation.*
 (b) **Driving Force.** Adaptations to different ecological niches due to natural selection.
3. **You have studied the story of Peppered Moth of England. Had the industries been removed, what impact could it have on the moth population. Discuss.**
 Ans. **Hint.** See text under Industrial Melanism. In case industries are removed, the black variants would be easily spotted by predators and hence will have reduced number.
4. **What are the key concepts in the evolution theory of Darwin?**
 Ans. **Hints.** The two key concepts of evolution theory of Darwin are **natural selection** and **branching descent**. They are the end results of certain phenomenon connected with reproduction and environment.
5. **Two organisms occupying a particular geographical area (say desert) show similar adaptive strategies. Taking examples, describe the phenomenon.**
 Ans. **Hints.** See text under convergent evolution.
6. **We are told that evolution is a continuing phenomenon for all living things. Are humans also evolving? Justify your answer.**
 Ans. **Hints.** Yes, see text under Human Evolution.
7. **Had Darwin been aware of Mendel's work, would he been able to explain the origin of variations. Discuss.**
 Ans. **Hints.** Yes, see chapter 5 "Principles of Inheritance and Variation".

Chapter—8

HUMAN HEALTH AND DISEASES

Very Short Answer Type Questions

1. Certain pathogens are tissue/organ specific. Justify the statement with suitable examples.

Ans. Pathogens are tissue/organ specific. For example
 (a) Malarial parasite infects RBCs and liver cells.
 (b) Typhoid causing bacteria infect intestine.

2. The immune system of a person is suppressed. In the ELISA test, the person was found to be positive to a pathogen.

- (a) Name the disease the patient is suffering from.
 (b) What is the causative organism?
 (c) Which cells of the body are affected by the pathogen?

Ans. (a) AIDS
 (b) HIV
 (c) Helper or T_4 lymphocytes.

3. Where are B-cells and T-cells formed? How do they differ from each other?

Ans. In red bone marrow. But B-cells mature in red bone marrow and T-cells mature in thymus. For Differences between B-lymphocytes and T-lymphocytes, See text Elementary Biology Page U3–28.

4. Given below are pairs of pathogens and diseases caused by them. Which of these is not a matching pair and why?

- | | |
|------------------------|-------------|
| (a) Virus | Common Cold |
| (b) <i>Salmonella</i> | Typhoid |
| (c) <i>Microsporum</i> | Filariasis |
| (d) <i>Plasmodium</i> | Malaria. |

Ans. (a) C pair is not matching.
 (b) *Microsporum* is a fungus which causes dermatomycosis, commonly known as ringworm disease.

5. What would happen to immune system if thymus gland is removed from the body of a person?

Ans. T- lymphocyte will not mature and immune system becomes weak.

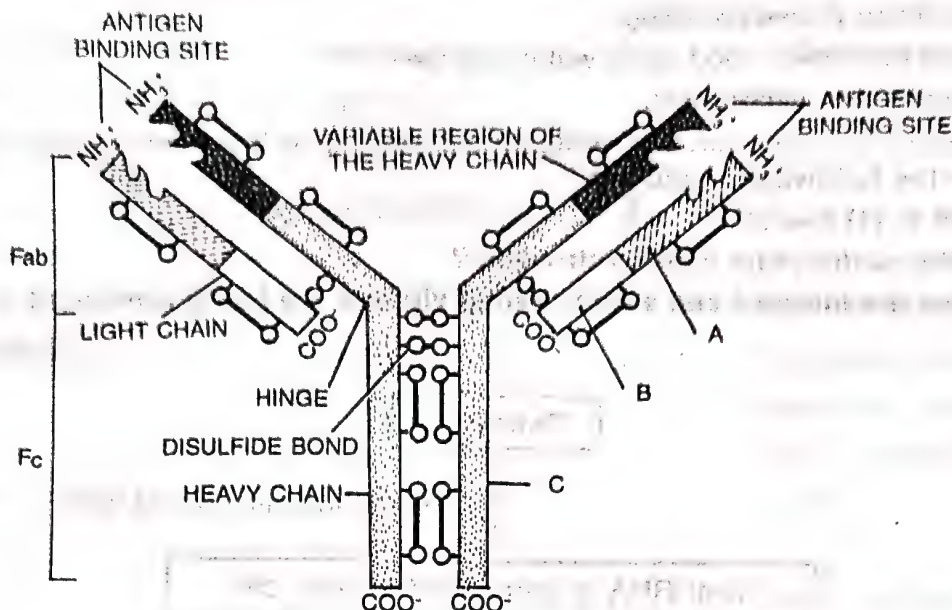
6. Many microbial pathogens enter the gut of humans alongwith food. What are the preventive barriers to protect the body from such pathogens? What type of immunity do you observe in this case?

Ans. (a) Lysozyme present in Saliva, HCL present in stomach.
 (b) Innate Immunity

7. What are interferons? How do interferons check infection of new cells?

Ans. Interferons are glycoproteins released by living cells in response to viral infection. Interferons make the surrounding cells resistant to viral attack by inhibiting multiplication of viral particles.

8. In the figure, structure of an antibody molecule is shown. Name the parts A, B and C.



Ans. A = Variable regions of light and heavy chain.

B = Constant region of light chain.

C = Constant region of heavy chain.

9. Why is an antibody molecule represented as H_2L_2 ?

Ans. Because each antibody molecule is formed of two heavy chains and two light chains which are represented by H_2 and L_2 respectively.

10. If a patient is advised Anti Retroviral Therapy, which infection is he suffering from? Name the causative organism.

Ans. The patient is suffering from AIDS (acquired immuno-deficiency syndrome). Its causative agent is HIV (human immunodeficiency virus).

Short Answer Type Questions

1. Differentiate between active immunity and passive immunity.

Ans. **Hint.** See text Elementary Biology Page U3-29 under differences between active immunity and passive immunity.

2. Differentiate between benign tumour and malignant tumour.

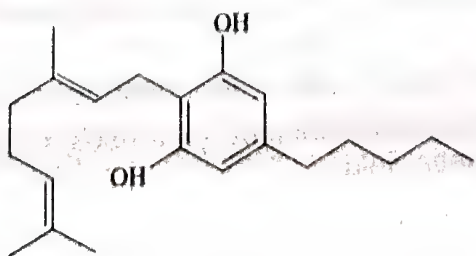
Ans. See text Elementary Biology Page U3-50 under differences between benign tumour and malignant tumour.

3. The outline structure of a drug is given below.

(a) Which group of drugs does this represent?

(b) What are the modes of consumption of these drugs?

(c) Name the organ of the body which is affected by consumption of these drugs.



Ans. (a) Cannabinoids

(b) Drink, food or smoked in cigarettes and pipes.

(c) Receptors in brain affect cardiovascular system.

4. Explain any three preventive measures to control microbial infection.

Ans. (i) Prevention of overcrowding.

(ii) Taking in of clean food, pure water and clean air.

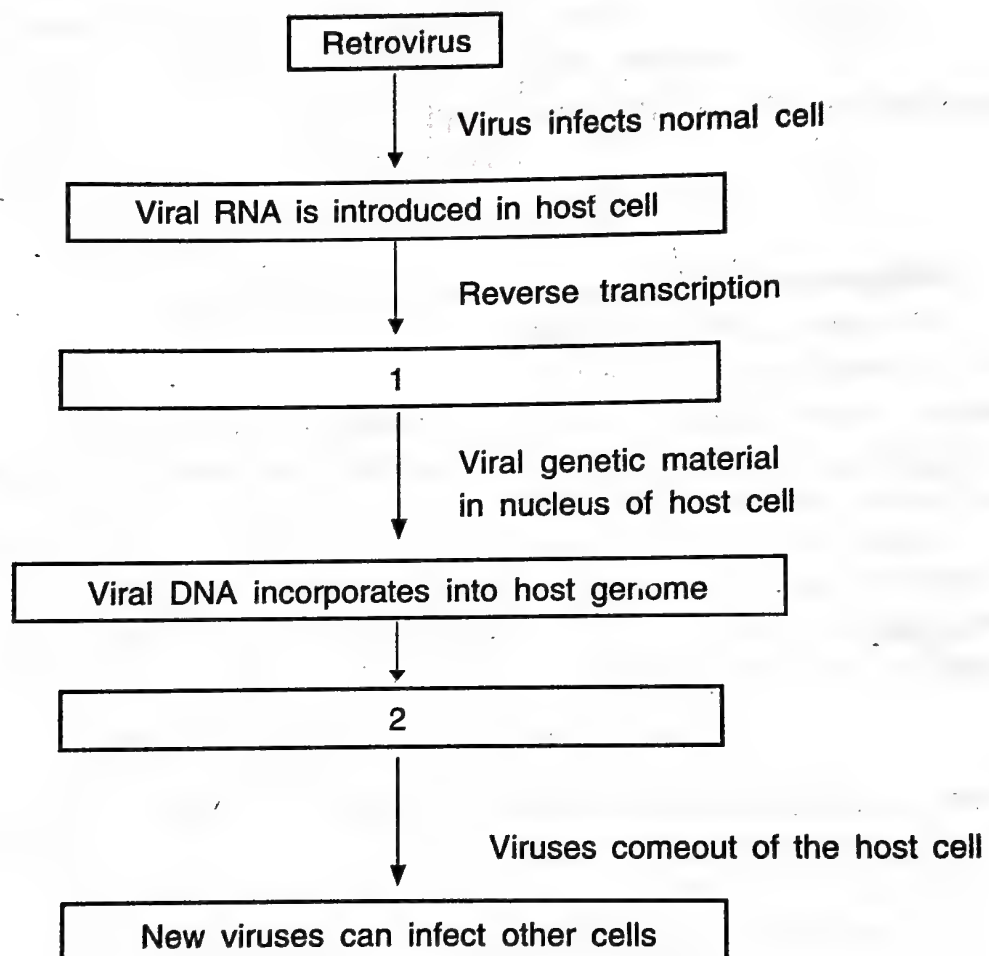
(iii) Hygiene and vaccination.

5. In the given flow diagram, the replication of retrovirus in a host is shown. Observe and answer the following questions.

(a) Fill in (1) and (2)

(b) Why is the virus called retrovirus?

(c) Can the infected cell survive while viruses are being replicated and released?



Ans. (a) (1) Viral DNA produced by reverse transcriptase.

(2) New viruses are produced.

(b) It is RNA virus where reverse transcription is performed to form viral DNA.

(c) Yes (e.g., HIV in macrophages).

6. Give the full form of CT and MRI. How are they different from each other? Where are they used?

Ans. (a) CT — Computed tomography. MRI — Magnetic resonance imaging

(b) **Difference.** CT is an invasive technique as it uses X-rays while MRI is a noninvasive technique as it uses magnetic field.

(c) **Use.** CT gives sectional and three dimensional picture of any part of the body while MRI gives better contrast of soft tissues. MRI, however, cannot be used on patients fitted with pace-maker and metal implants.

7. The following table shows certain diseases, their causative organisms and symptoms. Fill (a), (b), (c), (d), (e) and (f)

Name of the disease	Causative organism	Symptoms
(i) Ascariasis	<i>Ascaris</i>	— (a)
(ii) — (b)	<i>Trichophyton</i>	Appearance of dry, scaly lesion on various parts of the body
(iii) Typhoid	— (c)	High fever, weakness, headache, stomach pain, constipation.
(iv) Pneumonia	<i>Streptococcus pneumoniae</i>	— (d)
(v) — (e)	<i>Rhino viruses</i>	Nasal congestion and discharge, sorethroat, cough, headache.
(vi) Filariasis	— (f)	Inflammation in lower limbs

Ans. (a) Impaired digestion, intestinal pain, anaemia, damage to liver, brain and lungs, (b) Ringworm (c) *Salmonella typhi* (d) Chest pain, cough with rusty mucoid sputum, fever, rapid shallow breathing chill and headache. (e) Common cold (d) *Wuchereria bancrofti*.

8. Many secondary metabolites of plants have medicinal properties. It is their misuse that creates problems. Justify the statement with an example.

Ans. Numerous secondary plant metabolites are used as pharmaceuticals, stimulants, suppressants, tranquillizers, narcotics and hallucinogens. These are prescribed by the physician for the treatment of mental illness. The misuse of these plant metabolites makes the body dependent on them and leads to drug addiction.

9. Why cannabinoids are banned in sports and games?

Ans. Cannabinoids cause tachycardia (rapid heart beat), decrease vital capacity of lungs, impair perceptions and delay responses.

10. Drugs and alcohol give short-term 'high' and long-term 'damages'. Discuss.

Ans. Drugs and alcohol give feeling of intoxication and euphoria for only brief period soon after use. However, prolonged use causes permanent damage to vital body parts like liver, kidneys, lungs, cardiovascular system, etc.

11. What are life style diseases? How are they caused? Name any two such diseases.

Ans. Life Style Diseases are diseases caused by food preferences, lack of exercise, sedentary habits excessive club life, addictions, etc. Two such common diseases are obesity and hypertension.

Nutritional diseases (caused by food preferences) can be overcome by biofortification—lysine and tryptophan rich proteins, oils rich in omega-3 fatty acids, proper vitamins, micronutrients and other minerals. Some varieties of Maize, Carrot and Spinach have been developed to provide proper nutrients.

12. If there are two pathogenic viruses, one with DNA and other with RNA. Which would mutate faster? And Why?

Ans. RNA virus would mutate faster. RNA is quite labile due to presence of nitrogen base uracil and 2'OH group.

Long Answer Type Questions

1. Represent schematically the life cycle of a malarial parasite.

Ans. See the Text and Draw Schematic life cycle of malarial parasite Elementary Biology Page U3-12.

2. Compare the life style of people living in the urban areas with those of rural areas and briefly describe how the life style affects their health.

Ans. Hint. (i) Crowding (ii) Activity (iii) Contaminations (iv) Pollution (v) Sanitation (vi) Social Interactions.

3. Why do some adolescents start taking drugs. How can this be avoided?

Ans. Hints. (a) Reasons for Drug Abuse. See text
(b) Prevention and Control. See text

4. In your locality, if a person is addicted to alcohol, what kind of behavioural changes do you observe in that person? Suggest measures to overcome the problem.

Ans. Hints. (a) Behavioural Changes— (i) Euphoria ; (ii) Loss of Body Co-ordination ; (iii) Alteration in Behaviour ; (iv) Amnesia.
(b) Measures to overcome the problem— (i) Pressure on the family ; (ii) Telling silly antics ; (iii) Social Bycott.

5. What are the methods of cancer detection? Describe the common approaches for treatment of cancer.

Ans. Methods of Cancer Detection. See text
Treatment of Cancer. See text.

6. Drugs like LSD, barbiturates, amphetamines, etc. are used as medicines to help patients with mental illness. However, excessive doses and abusive usage are harmful. Enumerate the major adverse effects of such drugs in humans.

Ans. For Adverse Effects of these drugs. See text.

7. What is Pulse Polio Programme of Government of India? What is OPV? Why is it that India is yet to eradicate Polio?

Ans. See text

8. What are recombinant DNA vaccines? Give two examples of such vaccines. Discuss their advantages.

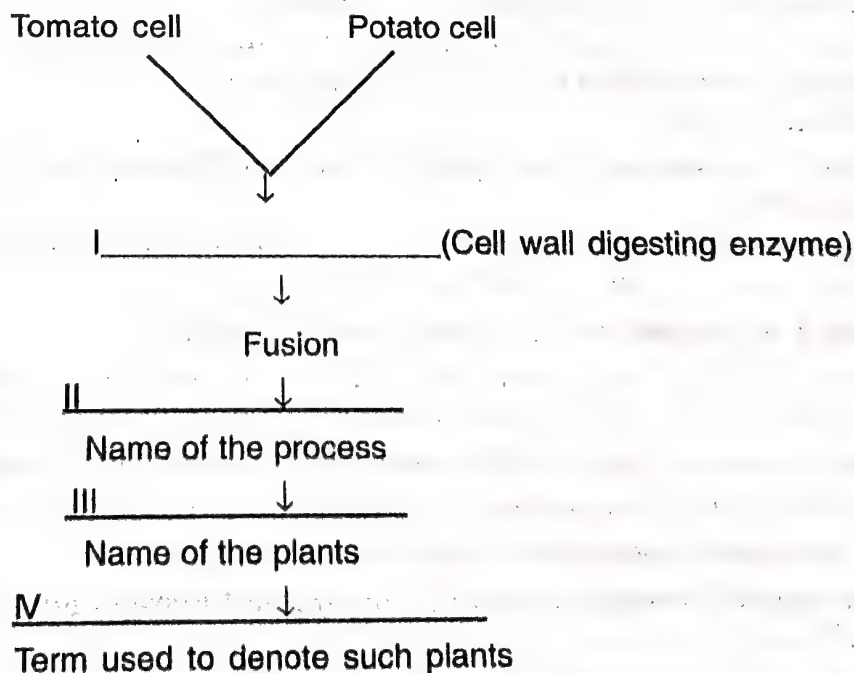
Ans. See text.

Chapter—9

STRATEGIES FOR ENHANCEMENT IN FOOD PRODUCTION

Very Short Answer Type Questions

1. Millions of chicken were killed in West Bengal, Assam, Orissa and Maharashtra recently. What was the reason?
Ans. The chickens were found infected with H5N1 virus that causes bird flu. The disease can be passed on the humans.
2. Can gamma rays used for crop improvement programmes prove to be harmful for health? Discuss.
Ans. Use of gamma rays for crop improvement are not harmful because gamma rays introduce mutations.
3. In animal husbandry, if two closely related animals are mated for a few generations, it results in loss of fertility and vigour. Why is this so?
Ans. Because recessive or harmful characters appear in the progeny.
4. In the area of plant breeding, it is important not only to preserve the seeds of the variety being cultivated, but also to preserve all its wild relatives. Explain with a suitable example.
Ans. Because wild relatives of cultivated plants have some genes that provide them herbicide tolerance or pest resistance and resistance against environmental stress.
5. Name a man-made cereal? Trace how it was developed and where is it used?
Ans. Triticale. It was developed by hybridisation between *Secale cereale* (rye) and *Triticum aestivum* (wheat).
6. Fill in the blanks



Ans. I – Cellulase ; II – Somatic Hybridisation ; III – Pomato ; IV – Somatic Hybrid.

7. A few statements are given below followed by a set of terms in a box. Pick the correct term and write it against the appropriate statement.

a. Mating of closely related individuals within the same breed.

b. Mating of animals of same breed but having no common ancestors on either side for 4-6 generations

c. Mating of animals of two different species

d. Breeding of animals belonging to different breeds

(i) Cross breeding, (ii) Inter-specific hybridization, (iii) Out breeding, (iv) Out crossing, (v) Inbreeding.

Ans. a – (v), b – (iv), c – (ii), d – (i)

8. What is meant by 'hidden hunger'?

Ans. It is consumption of food which is deficient in some essential nutrients like micronutrients vitamins and proteins.

9. Why are plants obtained by protoplast culture called somatic hybrids?

Ans. Plants obtained from protoplast culture are called somatic hybrids because they are formed from hybrid cells developed through fusion of genetically different somatic cells.

10. Why is it easier to culture meristems compared to permanent tissues?

Ans. Meristematic cells are undifferentiated and totipotent whereas cells of permanent tissues have lost the ability to divide.

11. Why are proteins synthesised from *Spirulina* called single cell proteins?

Ans. Single cells proteins are derived from biomass of unicellular micro-organisms. *Spirulina* is a cyanobacteria, therefore, proteins derived from its biomass are SCP.

12. A person who is allergic to pulses was advised to take a capsule of *Spirulina* daily. Give the reasons for the advise.

Ans. *Spirulina* is rich in proteins.

13. What is aquaculture? Give example of an animal that can be multiplied by aquaculture.

Ans. Aquaculture is growing and harvesting of aquatic organisms in different types of water bodies, such as in Freshwater and Salt water. Example. Fish, Prawn, Crustaceans, Molluscs.

14. What are the duties of a veterinary doctor in management of a poultry farm?

Ans. (i) Selection of disease free and suitable breed. (ii) Epidemic should not be there. (iii) Diseased birds should be treated and isolated (iv) Birds should be provided healthy feed and clean water.

15. Would it be wrong to call plants obtained through micro-propagation as 'clones'? Comment.

Ans. No. All the plants grown from the same explant are genetically similar. Hence they are clones of one another as well as parent plant.

16. What is emasculation? Why and when is it done?

Ans. Emasculation is the removal of anthers (male parts) from a bisexual flower, before the anthers mature. This prevents self-pollination in these flowers.

17. Discuss the two main limitations of plant hybridization programme.

Ans. (a) Different blooming periods. (b) Inhibition of pollen tube growth. (c) Cytoplasmic genic male sterility.

18. Interspecific crosses are rare in nature and intergeneric crosses almost unknown. Why?

Ans. Because of morphological and genic differences members of different species are reproductively isolated. Intergeneric hybrids do not occur as viability of a hybrid depends

upon its chromosomes derived from the two parents to form homologous pairs during gametogenesis. Whereas interspecific hybrids develop only between closely related species but even then they are mostly sterile, e.g., mule.

19. Differentiate between Pisciculture and Aquaculture.

Ans.	Pisciculture	Aquaculture
	1. Production of fishes is called pisciculture.	1. It involves production of all types of aquatic organisms in water bodies.
	2. Here fish feed is provided from outside.	2. There is small quantity of special feed from outside.

20. Give two important contributions of Dr. M.S. Swaminathan.

- Ans.** (i) Development of short duration high yielding varieties of rice, including scented Basmati.
 (ii) Development of light coloured wheat varieties (Sharbati Sinora, Pusa Lerma)
 (iii) He also developed hybrid varieties of maize, jowar and bajra.

21. The term 'desirable trait' can mean different things for different plants. Justify the statement with suitable examples.

- Ans.** For cereals, dwarfness is a desirable trait but for fodder plants tallness and branching are desirable. Other desirable traits include, higher yield, improved food quality, insect pest resistance, disease resistance to fungi, bacteria and viral diseases.

Short Answer Type Questions

1. You are planning to set up a Dairy Farm. Describe the various aspects you would consider before you start the venture.

- Ans.** (i) Quality of breed for increased milk yield; (ii) Quality and quantity of fodder from cattle; (iii) Cleanliness and hygiene for cattle and helpers.

2. It is said, that diseases are spreading faster due to globalisation and increased movement of people. Justify the statement taking the example of H5N1 virus.

- Ans.** The global movement of people and products are responsible for spread of infectious diseases.

3. Explain the concept of the Blue Revolution.

- Ans.** Blue Revolution means increase in (i) commercial fish farming; (ii) culturing prawns and lobsters; (iii) culturing shelled fishes (molluscs), etc.

4. A farmer was facing the problem of low yield from his farm. He was advised to keep a beehive in the vicinity. Why? How would the beehive help in enhancing yield?

- Ans.** Honey bee is the major pollinator of several crop plants. Keeping a beehive near the farm will ensure proper pollination of crop plants. Crop yield would, therefore, increase.

5. Life style diseases are increasing alarmingly in India. We are also dealing with large scale malnutrition in the population. Is there any method by which we can address both of these problems together?

- Ans.** Biofortification, i.e., breeding crops with higher contents of vitamins, micronutrients (minerals), good quality of proteins (with amino acid lysine) and good fats (with omega 3 fatty acids) is the most practical way to eradicate malnutrition and life-style diseases in human populations.

6. Name the improved characteristics of wheat that helped India to achieve green revolution.

- Ans.** (a) Semi-dwarf nature ; (b) High-yield ; (c) Disease Resistance ; (d) Protein content and quality ; (e) Short maturation period.

7. Suggest some of the features of plants that will prevent insect and pest infestation.

Ans. (a) Solid stems in wheat ; (b) Smooth leaves and nectarlessness in cotton ; (c) High aspartic acid, low nitrogen and sugar content in maize ; (d) Hairiness ; (e) Presence of toxic chemicals.

8. How can we improve the success rate of fertilization during artificial insemination in animal husbandry programme?

Ans. Multiple ovulation embryo transfer technology (MOET) is used, (a) A cow is given hormonal treatment with FSH to induce super ovulation. (b) The cow is then either inseminated artificially or mated with an elite bull. (c) The embryos at 8–32 cell stage are recovered and transferred to different surrogate mother cows.

9. What is meant by germplasm collection? What are its benefits.

Ans. The collection and preservation of all different wild varieties species so as to conserve their gene pool with all available alleles of all the gene of a crop plant is called germplasm collection. A very good collection is helpful in picking up the desired traits for incorporation in new improved variety.

10. It is easier to culture plant cells *in vitro* compared to animal cells. Why?

Ans. It is easier to culture plant cells because plants have more totipotent meristematic cells and can grow for unlimited generations. Animal cells are differentiated and in culture they stop growing after few generations and die.

11. The culture medium (nutrient medium) can be referred to as a 'highly enriched laboratory soil'. Justify the statement.

Ans. Culture medium is enriched soil for plants growing in laboratory as it provides all the nutrients required by cells to grow and divide. Such as Macronutrients (e.g., nitrogen, calcium). Micronutrients (e.g., copper, zinc), Vitamins (thiamine, nicotinic acid), Hormones (IAA, NAA, 2-4D) and Sucrose (2-4%).

12. Is there any relationship between dedifferentiation and the higher degree of success achieved in plant tissue culture experiments?

Ans. Yes. Dedifferentiation is key to development of cell division and growth of plant mass or callus. Callus can be subdivided at regular intervals and the subcultures allowed to differentiate and form plantlets.

13. "Give me a living cell of any plant and I will give you a thousand plants of the same type". Is this only a slogan or is it scientifically possible? Write your comments and justify them.

Ans. The above statement is scientifically possible, as by tissue culture technique a living cell can be made to multiply, forming a group of cells called callus. The cells of callus are isolated again and grown in new culture medium. The calluses thus formed are made to differentiate into plantlets by using different growth hormones in different concentration.

14. What is difference between a breed and a species? Give an example for each category.

Ans. Breed. A group of animals related by descent and similar in most characters like general appearance, features, size, configurations, etc. are said to belong to a 'breed', e.g., Sahiwal, Brown Swiss.

Species. Species is a group of interbreeding populations that are reproductively isolated from other such groups in nature. A species can have many breeds, e.g., *Bos indicus* (Cow).

15. Define the term 'stress' for plants. Discuss briefly the two types of stress encountered by plants.

Ans. 'Stress' for plants refers to unfavourable environmental condition that reduces growth and yield of plants. Plants encounter two types of stress.

(a) Drought, water-logging, snowing, high-temperature, salinity (Abiotic Stress Factors). Stomata get closed which leads to reduction in photosynthesis and plant yield.

(b) Animals and Man (Biotic Stress).

16. Discuss briefly how pure lines are created in animal husbandry.

Ans. In animal husbandry pure lines are created by inbreeding, i.e., mating between closely related animals of the same breed for several generations.

17. What are the physical barriers of a cell in the protoplast fusion experiment? How are the barriers overcome?

Ans. Hint. (i) Removal of cell wall. (ii) Fusion of the naked protoplasts.

18. Give few examples of biofortified crops. What benefits do they offer to the society?

Ans. Examples of biofortified crops — (i) Vitamin A enriched carrots, pumpkin and spinach. (ii) Vitamin C enriched bitter melon, Bathua, tomato, mustard. (iii) Calcium and iron enriched spinach and Bathua and (iv) protein enriched beans (broad lablab, French and garden peas).

Benefits to Society. (i) Protein content and its quality is improved. (ii) Oil content and quality is improved. (iii) Improved vitamin content. (iv) Improved micronutrient and mineral content.

Long Answer Type Questions

1. You are a Botanist working in the area of plant breeding. Describe the various steps that you will undertake to release a new variety.

Ans. Hint. See the text.

2. (a) The shift from grain to meat diets creates more demands for cereals. Why?

(b) A 250 kg cow produces 200 g of protein per day but 250 g of *Methylophilus methylotrophus* can produce 25 tonnes of protein. Name this emerging area of research. Explain its benefits.

Ans. (a) Formation of 1kg of meat in an animal requires 3–10 kg of cereals. Therefore, switch over from grain to meat will increase consumption of cereals.

(b) The emerging area of research is growth and evaluation of SCP microbes. The SCP microbes are being grown on industrial scale for obtaining biomass rich in proteins, minerals, vitamins, unsaturated fats and carbohydrates. This can overcome the problem of malnutrition.

3. What are the advantages of tissue culture methods over conventional method of plant breeding in crop improvement programmes?

Ans. Hint. See text under "Applications of Plant Tissue Culture".

4. 'Modern methods of breeding animals and plants can alleviate the global food shortage'. Comment on the statement and give suitable examples.

Ans. Hint. See the text

5. Does apiculture offer multiple advantages to farmers? List its advantages if it is located near a place of commercial flower cultivation.

Ans. Hint. See the text "under Apiculture".

6. (a) Mutations are beneficial for plant breeding. Taking an example, justify the statement.

(b) Discuss briefly the technology that made us self-sufficient in food production.

Ans. Hint. See the text. (a) Refer "Mutation Breeding". (b) "Plant Breeding"

7. Discuss how the property of plant cell totipotency has been utilised for plant propagation and improvement.

Ans. Hint. See the text

8. What are three options to increase food production? Discuss each giving the salient features, merits and demerits.

Ans. Hint. See the text. Refer to "Animal Farming, Poultry Farming and Fisheries".

Chapter—10

MICROBES IN HUMAN WELFARE

Very Short Answer Type Questions

1. **Why does 'Swiss Cheese' have big holes ?**
Ans. Due to evolution of large amounts of CO₂ by the bacterium involved in its processing.
2. **What are fermentors ?**
Ans. Fermentors or bioreactors are large-sized containers used for controlled fermentation activity of microbes for obtaining useful industrial products like antibiotics, alcoholic beverages, organic acids, solvents and bioactive molecules.
3. **Name a microbe used for statin production. How do statins lower blood cholesterol level ?**
Ans. **Microbe.** *Monascus purpureus*.
Mechanism. Statins are competitive inhibitors of enzyme β -hydroxy, β -methyl-glutaryl or HMG CoA reductase required for cholesterol synthesis. Therefore, cholesterol level decreases in the body.
4. **Why do we prefer to call secondary waste water treatment as biological treatment ?**
Ans. It involves microbial degradation of organic matter contained in sewage or waste water.
5. **What for nucleopolyhydro viruses are being used now-a-days ?**
Ans. They attack insects and other arthropods and kill them. Nucleopolyhydro viruses are, therefore, being used to kill insect pests of crops. The viruses have no effect on plants and nontarget animals.
6. **How has the discovery of antibiotics helped mankind in the field of medicine ?**
Ans. Antibiotics have helped mankind in treating most of the bacterial and fungal diseases.
7. **Why is distillation required for producing certain alcoholic drinks ?**
Ans. For increasing the alcohol content of the drinks.
8. **Write the most important characteristic that *Aspergillus niger*, *Clostridium butylicum* and *Lactobacillus* share ?**
Ans. Fermentation to produce organic acids.
9. **What would happen if our intestine harbours microbial flora exactly similar to that found in the rumen of cattle ?**
Ans. Microbial flora present in the rumen of cattle takes part in digestion of cellulose. Presence of this microbial flora will enable us to digest cellulose.
10. **Give any two microbes that are useful in biotechnology.**
Ans. *Escherichia coli*, *Agrobacterium tumefaciens*.
11. **What is the source organism for EcoRI restriction endonuclease ?**
Ans. *Escherichia coli*.
12. **Name any genetically modified crop.**
Ans. Bt Cotton.
13. **Why are blue-green algae not popular as biofertilizers ?**
Ans. They remain near the surface, produce copious mucilage and make the fields slippery.

14. Which species of *Penicillium* produces Roquefort cheese ?
 Ans. *Penicillium roqueforti*.
15. Name the states involved in Ganga action plan.
 Ans. Uttarakhand, U.P., Bihar and West Bengal.
16. Name any two industrially important enzymes.
 Ans. Lipase, Amylase.
17. Name an immunosuppressive agent.
 Ans. Cyclosporin.
18. Give an example of a rod-shaped bacteria.
 Ans. Tobacco Mosaic Virus (TMV).
19. What is the group of bacteria found in both the rumen of cattle and sludge of sewage treatment ?
 Ans. Methanogens.
20. Name the microbe used for production of Swiss cheese.
 Ans. *Propionibacterium sharmanii*.

Short Answer Type Questions

1. Why are flocs important in biological treatment of waste water ?
 Ans. Flocs are masses of semidecayed organic matter along with decomposer microbes which are surrounded by slime. They separate the organic matter from waste water. Flocs settle down in secondary tanks and take part in formation of sludge. They can be used as inoculum in biological treatment of waste water as well as source of biogas and manure.
2. How has the bacterium *Bacillus thuringiensis* helped us in controlling caterpillars of insect pests ?
 Ans. *Bacillus thuringiensis* produces an endotoxin called **cry protein**. As the caterpillar ingests the bacteria, the endotoxin is released in its gut. It produces holes in the gut wall and kills the caterpillar. The spores of the bacterium are sprinkled over the crops to kill the caterpillars. The gene producing endotoxin has been incorporated in certain crops (e.g., Bt Cotton) to control their insect pests.
3. How do mycorrhizal fungi help the plants harbouring them ?
 Ans. Mycorrhizal fungi help the plants in (i) Tolerating salinity; (ii) Absorption of water and prevent of drought; (iii) Solubilisation of organic matter and absorption of P, N and K from it; (iv) Protection from root pathogens.
4. Why are cyanobacteria considered useful in paddy fields ?
 Ans. Cyanobacteria are capable of nitrogen fixation. They, however, live in semiaquatic and aquatic habitats. Paddy fields contain water. Therefore, cyanobacteria can be inoculated in these fields for nitrogen fertility.
5. How was penicillin discovered ?
 Ans. Fleming (1928) found that growth of fungus *Penicillium* had killed bacteria in unwashed cultures of *Staphylococcus aureus*. The chemical extract of the fungus also killed the bacteria. It was named penicillin.
6. Name the scientists who were credited for showing the role of penicillin as antibiotic.
 Ans. Medicinal value of penicillin was shown by Chain and Florey (1939). The first use of penicillin as antibiotic for humans was made in 1941.
7. How do bioactive molecules of fungal origin help in restoring good health in humans ?
 Ans. (i) Cyclosporin from fungus *Trichoderma polysporum* is used as immunosuppressant in persons with immune problems (e.g., with organ transplant).

(ii) **Statins** from fungus *Monascus purpureus* (a Yeast) low body cholesterol by functioning as competitive inhibitor of enzyme required for cholesterol synthesis.

- 8.. **What roles do enzymes play in detergents that we use for washing clothers ? Are these enzymes produced from some unique microorganisms ?**
Ans. In detergents enzymes are used to remove stains. Two common types of stains are fat based and starch based. Therefore, detergents often contain enzymes lipase (for removing fat based stains) and amylase (for removing starch based stains). These enzymes are obtained from unique microorganisms like (i) **Lipase** from *Candida lipolytica* and (ii) **Amylase** from *Bacillus diastaticus*.
9. **What is the chemical nature of biogas ? Name an organism which is involved in biogas production ?**
Ans. Biogas mainly consists of methane, moderate quantity of carbon dioxide and small quantity of hydrogen. The organism involved in biogas production is mainly *Methanobacterium*, a methogen.
10. **How do microbes reduce the environmental degradation caused by chemicals ?**
Ans. Microbes can absorb and accumulate the chemicals as well as metabolise the same so as to clean the environment. The phenomenon is called **bioremediation**. *Pseudomonas putida* has been genetically modified (Chakravarty Bug) to metabolise most of the pollutant chemicals including oil spills.
11. **What is broad spectrum antibiotic ? Name one such antibiotic.**
Ans. A broad spectrum antibiotic is the one which is effective against both Gram (+) and Gram (–) bacteria, e.g., chloramphenicol.
12. **What are viruses parasiting bacteria called ? Draw a well labelled diagram of the same.**
Ans. Bacteriophage. Draw Fig. 10.2A of Elementary Biology.
13. **Which bacterium is used a clot buster ? What is its mode of action ?**
Ans. Genetically modified bacterium *Streptococcus* is called **clot buster** as its enzyme **streptokinase** (tissue plasminogen activator or TPA) is used in dissolving blood clots inside blood vessels.
14. **What are biofertilizers ? Give two examples.**
Ans. Biofertilizers are organisms that enrich the soil with nutrients, e.g., *Rhizobium*, *Azotobacter*.

Long Answer Type Questions

- Why is aerobic degradation more important than anaerobic degradation for the treatment of large volumes of waste waters rich in organic matter. Discuss.
- (a) Discuss about the major programmes that the Ministry of Environment and Forests, Government of India, has initiated for saving major Indian rivers from pollution.
 (b) Ganga has recently been declared the national river. Discuss the implication with respect to pollution of this river.
- Draw a diagrammatic sketch of biogas plant, and label its various components given below: Gas Holder, Sludge Chamber, Digester, Dung+water chamber.
- Describe the main ideas behind the biological control of pests and diseases.
- (a) What would happen if a large volume of untreated sewage is discharged into a river?
 (b) In what way anaerobic sludge digestion is important in sewage treatments?
- Which type of food would have lactic acid bacteria. Discuss their useful application.

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

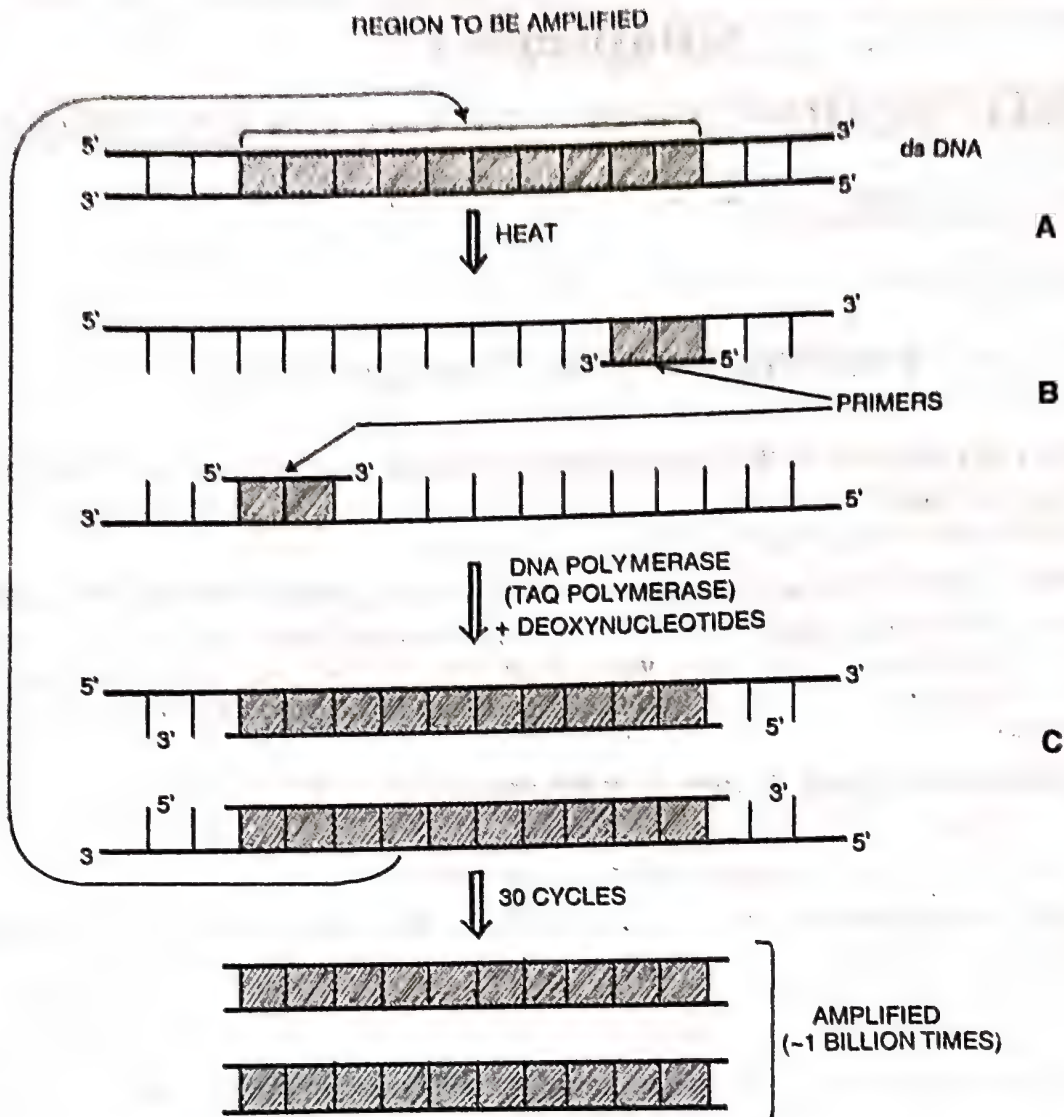
Chapter—11

BIOTECHNOLOGY : PRINCIPLES AND PROCESSES

Very Short Answer Type Questions

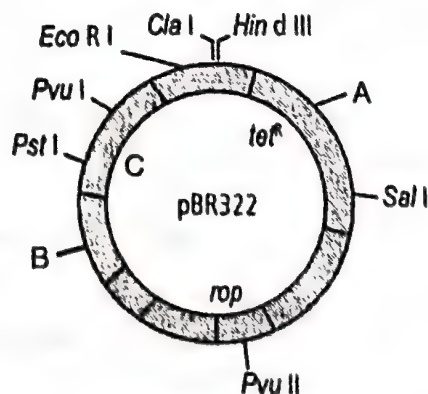
1. **How is copy number of the plasmid vector related to yield of recombinant protein?**
Ans. The copy number of the plasmid vector is directly related to yield of recombinant protein for coding and producing the recombinant protein.
2. **Would you choose an exonuclease while producing a recombinant DNA molecule?**
Ans. No, because exonuclease removes nucleotides from the free ends and does not produce DNA fragments with sticky ends. While producing a recombinant DNA molecule, plasmid (with no free ends) is to be cut and sticky ends are to be produced which an exonuclease cannot do.
3. **What does H in 'd' and 'III' refer to in the enzyme *Hin* d III?**
Ans. H – Haemophilus, in – influenza, d – strain.
 III – number of endonuclease from the bacterium.
4. **Restriction enzyme should not have more than one site of action in the cloning site of a vector. Comment.**
Ans. Presence of more than one recognition site in a vector will cause the restriction enzyme to act on more than one place and fragment the vector.
5. **What does 'competent' refer to in competent cells used in transformation experiments?**
Ans. 'Competent' means the ability of a treated cell (with CaCl_2) to pick up foreign DNA.
6. **What is the significance of adding proteases at the time of isolation of genetic material (DNA).**
Ans. Proteins form scaffolds and wrapping units for DNA. They have to be degraded with the help of proteases so that DNA becomes completely free for downstream treatment.
7. **While doing a PCR, 'denaturation' step is missed. What will be its effect on the process?**
Ans. In the absence of denaturation step, the two DNA strands will not open, primers will not anneal to the templates and no extension of DNA would occur. Therefore, there will be no amplification.
8. **Name a recombinant vaccine that is currently being used in vaccination program.**
Ans. Hepatitis – B vaccine
9. **Do biomolecules (DNA, protein) exhibit biological activity in anhydrous conditions?**
Ans. No. They become active only in the presence of water.
10. **What modification is done on the Ti plasmid of *Agrobacterium tumefaciens* to convert it into a cloning vector?**
Ans. The part responsible for virulence is deleted. However, tumour inducing gene is retained but this is used as recognition or cloning site.

11. Identify and explain steps 'A', 'B' and 'C' in the PCR diagram given below.



Ans. A — Denaturation of DNA ; B — Annealing ; C — Extension

12. Name the regions marked A, B and C.



Ans. A — Bam H1 ; B — origin of replication ; C — amp^R (ampicillin resistance) gene

Short Answer Type Questions

1. What is meant by gene cloning ?

Ans. Formation of multiple copies of a particular gene is called gene cloning. A gene is separated and ligated to a vector like plasmid. The recombinant plasmid is introduced into a plasmid

free bacterium through transformation. The transformed bacterium is made to multiply and form a colony. Each and every bacterium of the colony has a copy of the gene.

2. **Both a wine maker and a molecular biologist who had developed a recombinant vaccine claim to be biotechnologists. Who in your opinion is correct?**

Ans. Both. Biotechnology is the technological employment of biological entities and processes to generate products and services useful to human beings.

3. **A recombinant DNA molecule was created by ligating a gene to a plasmid vector. By mistake, an exonuclease was added to the tube containing the recombinant DNA. How does this affect the next step in the experiment, i.e., bacterial transformation?**

Ans. Exonuclease is unable to act on the plasmid (recombinant plasmid) as the latter has no free ends. Therefore, the mistaken addition of exonuclease will not have any impact on the next step in the experiment.

4. **Restriction enzymes that are used in the construction of recombinant DNA are endonucleases which cut the DNA at 'specific-recognition sequence'. What would be the disadvantage if they do not cut the DNA at specific-recognition sequence?**

Ans. Construction of recombinant DNA depends upon the availability of complementary sticky ends on both the passenger and vehicle DNAs. They are available only at specific recognition sequence of an endonuclease and nowhere else.

5. **A plasmid DNA and a linear DNA (both are of the same size) have one site for a restriction endonuclease. When cut and separated on agarose gel electrophoresis, plasmid shows one DNA band while linear DNA shows two fragments. Explain.**

Ans. Plasmid is a circular DNA. When an endonuclease acts on it, the DNA will become linear. It does not fragment further so that a single band is formed on agarose gel. When a linear DNA is cut by an endonuclease, it will form two fragments. Hence, two bands will appear on agarose gel.

6. **How does one visualise DNA on an agarose gel?**

Ans. DNA fragments are stained with ethidium bromide. They are irradiated with UV radiation. The DNA fragments fluoresce to produce bands of orange light.

7. **A plasmid without a selectable marker was chosen as vector for cloning a gene. How does this affect the experiment?**

Ans. In the absence of selectable marker, the worker will not be able to distinguish between transformants and nontransformants. Therefore, he will not be able to complete the experiment.

8. **A mixture of fragmented DNA was electrophoresed in an agarose gel. After staining the gel with ethidium bromide, no DNA bands were observed. What could be the reason?**

Ans. (i) Non-use of UV – radiations
(ii) Inadvert contamination with nuclease
(iii) Wrong fitting of electrodes.

9. **Describe the role of CaCl_2 in the preparation of competent cells?**

Ans. CaCl_2 is known to create transient pores in the bacterial cell walls for the entry of foreign DNA. This helps in transformation.

10. **What would happen when one grows a recombinant bacterium in a bioreactor but forget to add antibiotic to the medium in which the recombinant is growing?**

Ans. Antibiotic does not allow other bacteria to grow in the medium. In the absence of antibiotic, the desired bacterium may not be able to grow to its optimum level. The plasmids may also be lost, since maintaining a high copy number of plasmids is a metabolic burden on the bacteria.

Long Answer Type Questions

1. For selection of recombinants, insertional inactivation of antibiotic marker has been superseded by insertional inactivation of a marker gene coding for a chromogenic substrate. Give reasons.

Ans. Hint. Refer Text

2. Describe the role of *Agrobacterium tumefaciens* in transforming a plant cell.

Ans. Hint. Refer Text

3. Illustrate the design of a bioreactor. Highlight the difference between a flask in your laboratory and a bioreactor which allows cells to grow in a continuous culture system.

Ans. Draw Fig. 11.13.

Flask	Bioreactor
1. It is a laboratory scale testing of a process. 2. It provides a batch type culture. 3. No gadget can be connected.	1. It is a scaled up commercial press. 2. It provides a continuous culture. 3. Gadgets are attached to the reactor for optimum functioning.

Chapter—12

APPLICATIONS OF BIOTECHNOLOGY

Very Short Answer Type Questions

1. In view of the current food crisis, it is said, that we need another green revolution. Highlight the major limitations of the earlier green revolution.

Ans. (i) Genetic cap for improvement of yield.
 (ii) Extensive use of fertilisers and pesticides which are polluting the water bodies, soil and food items.
 (iii) It was related to better management practices which can improve food availability to a limited extent.

2. Expand GMO. How is it different from a hybrid?

Ans. (a) **GMO** — Genetically modified organism.
 (b) **Differences between GMO and Hybrid**

GMO	Hybrid
1. Formation of GMO does not require crossing between different organisms.	1. It is formed as a result of crossing between two different organisms.
2. One or more foreign genes are incorporated in GMO.	2. It contains complete genomes of two different organisms.
3. A completely new trait has been introduced.	3. Only the existing traits are improved.

3. Differentiate between diagnostics and therapeutics. Give one example for each category.

Diagnostics	Therapeutics
1. It finds out the cause and nature of the disease.	1. It treats patients to cure them of the disease.
2. It provides logic basis for treatment. Example : ELISA test or HIV.	2. It provides relief from the disease. Example : Antibiotic for bacterial infection.

4. Give the full form of ELISA. Which diseases can be detected using it?

Ans. ELISA — Enzyme Linked Immunosorbent Assay. The diseases detected by ELISA are Hepatitis –B Virus, Hepatitis –C Virus and HIV.

5. Can a disease be detected before its symptoms appear? Name the principle involved.

Ans. Yes. The principle involved is "Molecular Diagnosis".

6. Many proteins are secreted in their inactive form. This is also true of many toxic proteins produced by micro organisms. Explain how the mechanism is useful for the organism producing the toxin?

Ans. The inactive toxic protein requires a particular pH, temperature or biochemical for becoming active. The condition is not found in the microorganism producing the inactive protein but occurs in the organism against which it is effective.

7. While creating genetically modified organisms, genetic barriers are not respected. How can this be dangerous in the long run?

Ans. (i) Genetic Pollution ; (ii) Super Weeds ; (iii) Super Insecticides.
(iv) **Proteins.** Foreign genes operate through formation of proteins. However, foreign proteins are generally attacked by the defence system resulting in damage of biochemicals.
(v) **Gene Effects.** Genes may change expression with age and environment. Gene P₅₃ is anticancer gene but it starts precipitating ageing effect after certain period of activity.

8. Why has the Indian Parliament cleared the second amendment of the country's patents bill?

Ans. As per this bill a three-tier mechanism of Institutional Biosafety committees (IBCs) has been set up. These committees make decisions and coordinate research regarding the validity of GM research and safety of introducing GM organisms for public services.

9. Give any two reasons why the patent on *Basmati* should not have gone to an American Company.

Ans. (i) Basmati or scented rice has been in cultivation in India since prehistoric times. (ii) Simply by producing hybrid of Basmati the American company could not claim to have patent right over all scented forms of Rice.

10. How was insulin obtained before the advent of rDNA technology? What were the problems encountered?

Ans. Before the advent of rDNA technology, insulin was obtained from slaughtered cattle and pigs. **Problems.** (i) Insulin obtained from slaughtered cattle and pigs is slightly different from human insulin. It has harmful effect over long periods. (ii) The drug has been eliciting immune response in some patients.

11. With respect to understanding diseases, discuss the importance of transgenic animal models.

Ans. (i) Transgenic animals are being used as models to study how genes take part in development of diseases. (ii) The animals are also used to study various lines of treatment and their effect. (iii) Vaccine safety is tested over transgenic animals before being tried over humans.

12. Name the first transgenic cow. Which gene was introduced in this cow?

Ans. **First transgenic Cow—Rosie.** Milk with high protein content (2.4 gm/litre)
Introduced Gene. Human α -lactalbumin gene.

13. PCR is a useful tool for early diagnosis of an infectious disease. Elaborate.

Ans. PCR is useful for amplification or increase in number of DNA molecules. The technique is used in artificial multiplication of DNA of the infectious agent and its proper diagnosis.

14. What is GEAC and what are its objectives?

Ans. **GEAC.** Genetic Engineering Approval Committee. **Objectives.** (i) Examine the validity of GM research. (ii) Inspect the safety of use of GMOs.

15. For which variety of Indian rice the patent was filed by a USA Company?

Ans. Indian Basmati Rice was crossed with a semi-dwarf variety and was claimed to be new scented variety for which patent was filed by a U.S.A. company.

16. Discuss the advantages of GMO.

Ans. (1) Pest Resistance Crops ; (2) Tolerance ; (3) Reduction in Post-harvest Losses ; (4) Prevention of Early Exhaustion of Fertility of soil ; (5) Increasing Nutritional Value of Food ; (6) Herbicide Resistance ; (7) Alternative Resources to Industries ; (8) Disease Resistance ; (9) Phytoremediation.

Short Answer Type Questions

1. Gene expression can be controlled with the help of RNA. Explain the method with an example.

Ans. The technology is called RNA Interference (RNA I). A nematode *Meloidogyne Incognita* infects the roots of tobacco plants and causes a great reduction in yield. A novel strategy was coined by Fire and Mello in 1998 to prevent this infestation that was based on the process of RNA interference (RNAI). RNAI takes place in all eukaryotic organisms as a method of cellular defense. This method involves silencing of a specific mRNA.

Using *Agrobacterium* vectors, nematode specific genes are introduced into the host plant (tobacco plant). The introduction of DNA was such that it produced both sense and anti-sense RNA in the host cells. These two RNAs being complementary to each other formed a dsRNA (double stranded RNA) that initiated RNAI.

2. Ignoring our traditional knowledge can we prove costly in the area of biological patenting? Justify.

Ans. Traditional knowledge is one that has been accumulated by local communities, tribesmen and medical practitioners over long period of history regarding their use in medicine and other purposes. Instead of going through the whole process of research from the beginning, traditional knowledge can be tested and the product refined for commercial exploitation. This will reduce time, effort and expenditure towards biological patenting.

3. Highlight any four areas where genetic modification of plants has been useful.

Ans. Genetically modified plants have been developed with a focus on following improved characteristics. (i) Tolerance of abiotic stresses like drought or salinity. (ii) Resistance to virus, herbicide and pest. (iii) Better nutritional value. (iv) Increased efficiency in mineral utilisation.

4. What is a recombinant DNA vaccine? Give two examples.

Ans. Recombinant DNA vaccine is the one that has been formed with the help of recombinant DNA and contains only immunogenic protein or other biochemical which causes development of antibodies against the disease, e.g., Hepatitis B, Influenza B, Meningitis.

5. Why is it that the line of treatment for a genetic disease is different from infectious diseases?

Ans. Genetic disease is caused by improper functioning of some gene which results in non functioning of enzymes, non formation or wrong formation of proteins and other biochemicals. Therefore, genetic diseases cannot be treated by methods used in infections like killing of pathogens and strengthening of immune system.

6. Discuss briefly how a probe is used in molecule diagnostics.

Ans. Gene probe is a radioactively labelled cloned section of DNA that is used to detect identical sections of nucleic acid by means of pairing between complementary bases. In Southern blotting, DNA segments are diagnosed. In Northern blotting, RNA is identified.

7. Who was the first patient who was given gene therapy? Why was the given treatment recurrent in nature?

Ans. A four year old girl (Ashanti deSilva) in 1990 who was treated for ADA deficiency in treatment of SCID. ADA gene was taken from leucocytes of a healthy person and inserted in a retrovirus. It was injected into lymphocyte stem cells of the patient alongwith helper virus. Lymphocytes produced from these stem cells had normal ADA gene and the immune system of the patient became functional. A permanent cure can be possible only when functional ADA gene is introduced in cells of the early embryo. This is not possible as diagnosis of the future disease cannot be undertaken before hand. Therefore, the treatment is recurrent in nature.

8. Taking examples under each category. Discuss upstream and downstream processing.

- Ans.** **Upstream Processing.** It is the start of microbial activity for an industrial process. Upstream processing includes a proper nutrient solution, a pure strain of desired microbe and optimum conditions like pH, aeration, temperature etc.
- Downstream Processing.** It is obtaining the products of a microbial activity. It is carried out when sampling report indicates the completion of biosynthetic phase and presence of optimum product in the cells. Major biomass is taken out, crushed and the product separated, e.g., antibiotic.
9. **Define Antigen and Antibody. Name any two diagnostic kits based upon them.**
- Ans.** **Antigen—** It is any foreign substance, toxin, particle or pathogen which induces the immune system of the body to produce cells and antibodies to dispose off the same.
- Antibody—** It is a glycoprotein or immunoglobulin that possesses specific amino acid sequences by which it can interact with a specific antigen.
- Diagnostic kits (i) ELISA for HIV ; (ii) Pregnancy test kit.
10. **ELISA technique is based on the principles of antigen-antibody interaction. Can this technique be used in the molecular diagnosis of a genetic disorder. Such as phenylketonuria?**
- Ans.** Yes. The technique can be used against the enzyme phenylalanine hydroxylase by developing an antibody against it. The patient where the enzyme is absent would give a negative result while a normal individual would give a positive result.
11. **How is a mature functional insulin hormone different from its prohormone form?**
- Ans.** Prohormone contains an extra 35 amino acids long c-peptide. It is removed during maturation of insulin from proinsulin.
12. **Gene therapy is an attempt to correct a genetic defect by providing a normal gene into the individual. By this the normal function can be restored. An alternate method would be to provide the gene product (protein/enzyme) known as enzyme replacement therapy, which would also restore the function. Which in your opinion is a better option? Give reason for your answer.**
- Ans.** Gene therapy is a better option as it cures the patient for the rest of life. Enzyme therapy can be successful only if the enzyme is given regularly to the patient.
13. **Transgenic animals are the animals in which a foreign gene is expressed. Such animals can be used to study the fundamental biological process, phenomenon as well as for producing products useful for mankind. Give one example for each type.**
- Ans.** (i) Use of transgenic animals for the study of fundamental biological processes. Study of biological aspects of growth by insulin like growth factors (1GF-I and 1GF-II).
- (ii) Use of transgenic animals for obtaining useful products : Transgenic cow — Rosie whose milk is rich in α -lactalbumin protein.
14. **When a foreign DNA is introduced into an organism, how is it maintained in the host and how is transferred to the progeny of the organism?**
- Ans.** Foreign DNA is generally ligated to a plasmid and introduced in a host. As the plasmid replicates the foreign DNA also gets replicated. When the host organism divides, its progeny also receives the plasmid with foreign DNA.
15. **Bt cotton is resistant to pests, such as lepidopterans, dipterans and coleopterans. Is Bt cotton also resistant to other pests as well ?**
- Ans.** Bt cotton contains genes against lepidopterans, dipterans and coleopterans. However, these genes are not effective against all the types of insect pests that may happen to attack cotton.

Long Answer Type Questions

1. **A patient is suffering from DNA deficiency. Can he be cured? How?**
- Ans.** Yes, with the help of gene therapy. See short answer type question 7.

2. **Define transgenic animals. Explain in detail any four areas where they can be utilised.**

Ans. See Elementary Biology under headings — Transgenic fish, Transgenic mice, Transgenic sheep, Transgenic cows.

3. **You have identified a useful gene in bacteria. Make a flow chart of the steps that you would follow to transfer this gene to a plant.**

Ans. 1. Isolation of useful gene by employing restriction endonuclease

↓

2. Making a cut in T-DNA with the same restriction endonuclease

↓

3. Producing a recombinant T-DNA with the help of T_4 DNA ligase.

↓

4. Transfer of recombinant DNA into plant cells.

↓

5. Screening the plant cells for transformation

↓

6. Selection of transformed cells and regeneration of plants from transformed cells. They would be transgenic plants.

4. **Highlight five areas where biotechnology has influenced our lives.**

Ans. Hints : (i) Availability of Biochemicals ; (ii) Gene Therapy ; (iii) Molecular Diagnosis ; (iv) Biofortification of crop yield ; (v) Environmental Protection.

5. **What are the various advantages of using genetically modified plants to increase the overall yield of the crop?**

Ans. Hint. See Elementary Biology under Advantages of GM Plants.

6. **Explain with the help of one example how genetically modified plants can :**

(a) Reduce usage of chemical pesticides.

(b) Enhance nutritional value of food crops.

Ans. (a) See Elementary Biology under "Pest Resistant Plants".

(b) See Elementary Biology Text

7. **List the disadvantages of insulin obtained from the pancreas of slaughtered cows and pigs.**

Ans. Hint. (i) and (ii) See very short type question 10. (iii) A slaughtered animal produces very little hormone so that the demand was always higher than the supply. (iv) It is unethical to slaughter animals for obtaining the drug. (v) Contamination was quite common.

8. **List the advantages of recombinant insulin.**

Ans. (i) Recombinant insulin is exactly similar to human insulin and is therefore, also called humulin. (ii) It is available in pure form with little chances of contamination. (iii) There is no slaughtering of animals. (iv) There is no immune response or any other side effect. (v) There is enough manufacturing capacity so that the chances of short supply are little.

9. **What is meant by the term bio-pesticide? Name and explain the mode of action of a popular bio-pesticide.**

Ans. Hint. Biopesticide is a living organism, its product or gene is able to kill or repel a pest. (i) It does not pollute that environment. (ii) It does not enter the food chains. (iii) It is highly specific. (iv) Bt Toxin see Elementary Biology text.

10. **Name the five key tools for accomplishing the tasks of recombinant DNA technology. Also mention the functions of each tool.**

Ans. Hints. (i) Restriction Endonucleases. (ii) Gel Electrophoresis. (iii) T_4 ligase. (iv) Vector and competent host. (v) DNA delivery system.

Chapter—13

ORGANISMS AND POPULATIONS

Very Short Answer Type Questions

1. Species that can tolerate narrow range of temperature are called _____
 Ans. Stenothermic
2. What are eurythermic species?
 Ans. Species that can tolerate wide range of temperature variations are called eurythermic.
3. Species that can tolerate wide range of salinity are called _____
 Ans. Euryhaline.
4. Define stenohaline species.
 Ans. It is a species which lives within a narrow range of salinity.
5. What is interaction between two species called ?
 Ans. Interspecific interaction (called symbiosis by De Bary 1879).
6. What is commensalism ?
 Ans. It is interspecific interaction in which one species is benefitted while the other is neither harmed nor benefitted.
7. Name the association in which one species produces poisonous substance or a change in environmental conditions that is harmful to another species.
 Ans. Amensalism.
8. What is mycorrhiza ?
 Ans. It is symbiotic or mutually beneficial association between a fungus and roots of higher plants.
9. Emergent land plants that can tolerate the salinity of the sea are called _____
 Ans. Mangrove plants.
10. Why do high altitude areas have brighter sunlight and lower temperatures as compared to the plains.
 Ans. **Brighter Sunlight.** Fewer dust particles are present at high altitudes so that there is little absorption of incoming sunlight by the atmosphere.
Lower Temperature. Atmospheric temperature depends upon trapping of infra-red radiations and their re-radiation back to earth. At high altitude the atmosphere is thinner with lesser trapping of infra-red radiations.
11. What is homeostasis ?
 Ans. Homeostasis is the maintenance of constancy of the internal environment of a body despite changes in the external environment.
12. Define aestivation.
 Ans. It is the condition of rest in a cool shady place during the hot dry period of the summer day.
13. What is diapause and its significance ?

Ans. It is development of dormant stage by a growing organism in order to overcome unfavourable environmental condition.

Significance. Passing unfavourable conditions without any harm.

14. What would be the growth rate pattern, when the resources are unlimited.

Ans. Exponential

15. What are the organisms that feed on the plant sap and other plant parts called.

Ans. Sucking and chewing organisms (Phytophagous).

16. What is high altitude sickness ? Write its symptoms.

Ans. High altitude or mountain sickness is the feeling of discomfort when somebody from plains visits an area of high altitude. Its symptoms are nausea, fatigue and heart palpitation. The reason is low oxygen content of atmosphere which is thinner. The symptoms disappear after sometime (by increasing breathing rate, increased production of RBCs and decreased binding capacity of haemoglobin).

17. Give a suitable example for commensalism.

Ans. Cattle egret and grazing cattle.

18. Define ectoparasite and endoparasite and give suitable examples.

Ans. **Ectoparasite.** It is a parasite that lives on the surface of host that feeds on blood, sap or external tissues, e.g., aphid, lice, fleas, *Cuscuta*.

Endoparasite. It is a parasite that lives inside the body of host, e.g., *Ascaris*, *Plasmodium*.

19. What is brood parasitism ? Explain with the help of an example.

Ans. It is caring, hatching and rearing of young birds by a different bird along with its own nestlings. Cuckoo is a brood parasite over crow.

Short Answer Type Questions

1. Why are coral reefs not found in the regions from West Bengal to Andhra Pradesh but are found in Tamil Nadu on the east coast of India.

Ans. Coral reefs occur in areas of high salinity, optimal temperature and little siltation. East coast from West Bengal to Andhra Pradesh has river deltas which reduce salinity, temperature and cause a lot of siltation. Therefore, coral reefs do not occur here. However, the coastal areas of Tamil Nadu do not have such a disturbance so that coral reefs occur over here.

2. If a fresh water fish is placed in an aquarium containing sea water, will the fish be able to survive ? Explain giving reasons.

Ans. Fresh water fish placed in sea water aquarium will not be able to survive for long due to (i) Exosmosis or loss of body water due to high osmolarity of sea water. (ii) Nondrinking habit of fresh water fish. (iii) Tendency to eliminate large quantity of urine. (iv) Tendency to absorb salt and not excrete the same.

3. Why do all fresh water organisms have contractile vacuoles whereas majority of marine organisms lack them.

Ans. In fresh water organisms, there is tendency of water to enter the body due to endosmosis. Excess water has to be eliminated from their body. This is done by contractile vacuoles in many cases.

In marine organisms, there is tendency for exosmosis due to high outside salt content. It is compensated by intake of salt water. No contractile vacuoles are required.

4. Define heliophytes and sciophytes. Name a plant from your locality that is either heliophyte or sciophyte.

Ans. Plants growing in bright light are called **sun plants** or **heliophytes**, e.g., *Prosopis*.

Plants growing in partial shade or low intensity light are called **shade plants** or **sciophytes**. e.g., *Nyctanthes*.

5. Why so submerged plants receive weaker illumination than exposed floating plants in a lake ?

Ans. A lot of sunlight is lost while passing through water before reaching the submerged plants. Direct and hence full sunlight falls on plants floating on the surface of water.

6. In the sea shore, the benthic animals live in sandy, muddy and rocky substrata and accordingly developed the following adaptations — (a) Burrowing, (b) Building Cubes and (c) Hold fasts/peduncle. Find the suitable substratum against each adaptation.

Ans. (a) Burrowing— Sandy substratum. (b) Building Cubes— Muddy substratum, (c) Hold fasts/peduncle — Rocky substratum.

7. Categorise the plants into hydrophytes, halophytes, mesophytes and xerophytes. Give reasons for your answer. (a) *Salvinia*. (b) *Opuntia*, (c) *Rhizophora*, (d) *Mangifera*.

Ans. (a) *Salvinia* — Hydrophyte as it grows in water.
 (b) *Opuntia* — Xerophyte as it is succulent and grows in dry areas.
 (c) *Rhizophora* — Halophyte as it occurs in saline marshes on sea shores.
 (d) *Mangifera* — Mesophyte because it grows in soils with good moisture.

8. In a pond, we see plants which are free floating, rooted submerged, rooted emergent, rooted with floating leaves. Write the type of plant against each of them. (a) *Hydrilla* (b) *Typha* (c) *Nymphaea* (d) *Lemna* (e) *Vallisneria*.

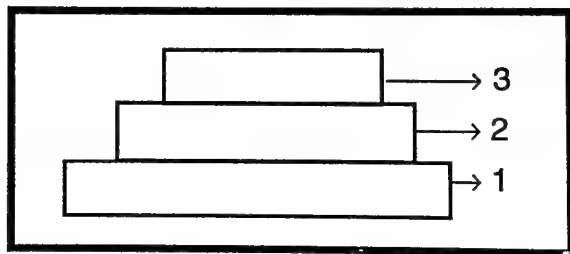
Ans. (a) *Hydrilla* — Submerged. (b) *Typha* — Rooted emergent. (c) *Nymphaea* — Root with floating leaves. (d) *Lemna* — Free floating. (e) *Vallisneria* — Rooted submerged.

9. Density of a population in a habitat is measured in different units. Write the unit of measurement against Bacteria, Banyan, Deer, Fish and Grass.

Ans. (a) Bacteria. Number/volume (b) Banyan. Biomass/area; (c) Deer. Number/area; (d) Fish. Weight/area; (e) Grass. Coverage/area.

10. (a) Label the three tiers 1, 2, 3 in the given age pyramid.

(b) What type of population growth is represented by this age pyramid ?



Ans. (a) 1.—Pre-reproductive. 2. — Reproductive. 3. —Post-reproductive.
 (b) Young / expanding population.

11. In an association of two animal species, one is a termite which feeds on wood and the other is protozoan *Trichonympha* present in the gut of the termite. What type of association they establish ?

Ans. Mutually beneficial or mutualism. *Trichonympha* brings about digestion of wood. The digested product is shared by *Trichonympha* as well as termite.

12. Lianas are vascular plants rooted in the ground and maintain erectness of their stem by making use of other trees for support. They do not maintain direct relation with those trees. Discuss the type of association the lianas have with the trees.

Ans. Commensalism, as lianas are benefitted by the support of other trees while the trees are neither benefitted nor harmed.

13. Give the scientific names of any two microorganisms inhabiting the human intestine.

Ans. *Streptococcus faecalis*, *Escherichia coli*.

14. What is tree line?

Ans. It is altitude as well as latitude beyond which no tree grows. Only shrubs and herbs are found.

15. Define 'zero population growth rate'. Draw an age pyramid for the same.

Ans. Zero population growth occurs when natality and immigration is exactly balanced by mortality and emigration.

Draw fig. 13.14 (middle). It is like an inverted bell.

16. List any four characters that are employed in human population census.

Ans. (i) Population; (ii) Natality; (iii) Mortality; (iv) Sex distribution ; (v) Age distribution.

17. Give one example for each of the following types : (a) Migratory animal (b) Camouflaged animal (c) Predator animal (d) Biological control agent (e) Phytophagous animal (f) Chemical defense agent.

Ans. (a) Migratory Animal. Arctic Tern (*Sterna parasissaea*) ; (b) Camouflaged Animal. Praying Mantis (*Mantis religiosa*) ; (c) Predator Animal. Lion; (d) Biological Control Agent. *Gambusia* against mosquitoes; (e) Phytophagous Animal. Caterpillars of insect pests; (f) Chemical Defence Agent. Cardiac glycosides in *Calotropis*.

18. Fill in the blanks

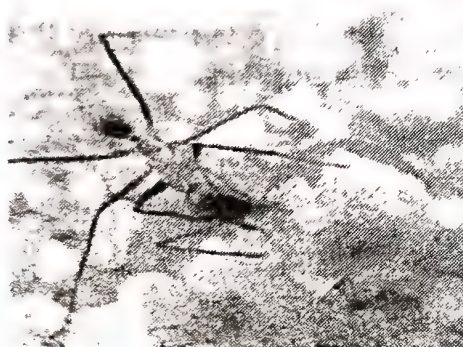
Species A	Species B	Type of Interaction	Example
+	-	(i)	(ii)
+	+	(iii)	(iv)
+	(v)	Commensalism	(vi)

Ans. (i) Predation; (ii) Lion attacking deer ; (iii) Mutualism; (iv) Lichen, between fungus and alga; (v) Zero ; (vi) Cattle egret and cattle.

19. Observe the set of four figures A, B, C and D and answer the following questions (i) Which one of the figures shows mutualism? (ii) What kind of association is shown in D? (iii) Name the organisms and the association in C. (iv) What role is the insect performing in B?



A



B



C



D

Ans. (i) Mutualism in Fig A between butterfly and flower.

- (ii) Predation in Fig. D, Leopard attacking deer.
- (iii) Commensalism in Fig C, Cattle Egret and Cattle.
- (iv) Phytophagy in B, Insect sucking plant sap.

Long Answer Type Questions

1. Comment on the following figures: 1, 2 and 3:

A, B, C, D, G, P, Q, R, S are species

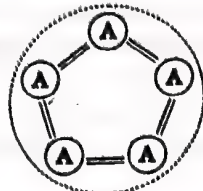


Fig. 1

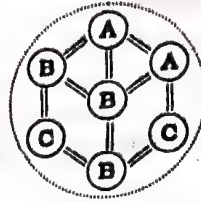


Fig. 2

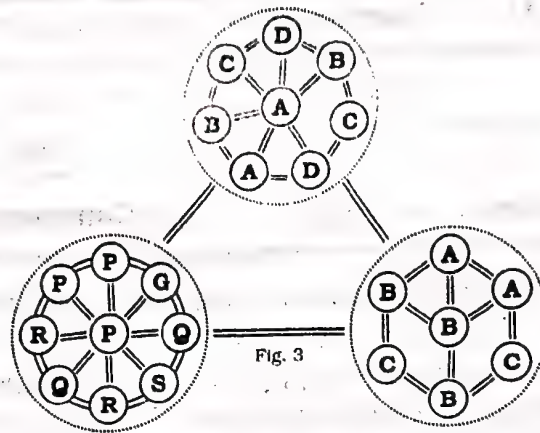
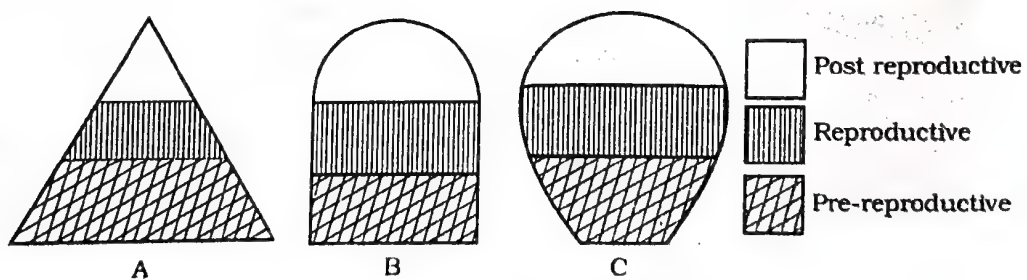
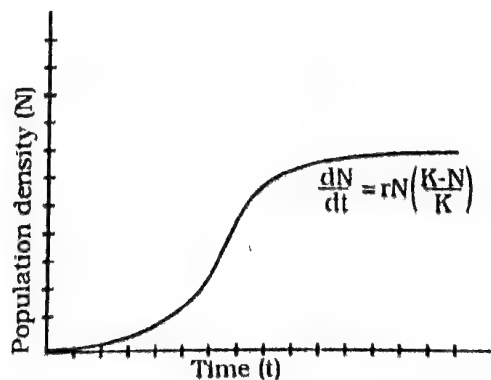


Fig. 3

2. An individual and a population has certain characteristics. Name these attributes with definitions.
3. The following diagrams are the age pyramids of different populations. Comment on the status of these populations.



4. Comment on the growth curve given below.



5. A population of *Paramecium caudatum* was grown in a culture medium. After 5 days the culture medium became overcrowded with *Paramecium* and had depleted nutrients. What will happen to the population and what type of growth curve will the population attain? Draw the growth curve.
6. Discuss the various types of positive interactions between species.
7. In an aquarium two herbivorous species of fish are living together and feeding on phytoplanktons. As per the Gause's Principle, one of the species is to be eliminated in due course of time, but both are surviving well in the aquarium. Give possible reasons.
8. While living in and on the host species, the animal parasite has evolved certain adaptations. Describe these adaptations with examples.
9. Do you agree that regional and local variations exist within each biome? Substantiate your answer with suitable example.
10. Which element is responsible for causing soil salinity? At what concentration does the soil become saline?
11. Does light factor affect the distribution of organisms? Write a brief note giving suitable examples of either plants or animals.
12. Give one example for each of the following:

	Ans.
i. Eurythermal plant species _____	<i>Artemisia</i>
ii. A hot water spring organism _____	<i>Thermus aquaticus</i>
iii. An organism seen in deep ocean trenches _____	<i>Euplectella</i>
iv. An organism seen in compost pit _____	Earthworm
v. A parasitic angiosperm _____	<i>Cuscuta</i>
vi. A stenothermal plant species _____	Coconut Palm
vii. Soil organism _____	Earthworm
viii. A benthic animal _____	Agler Fish
ix. Antifreeze compound seen in antarctic fish _____	Anti Freeze Protein
x. An organism which can conform _____	Reptile — wall Lizard

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

Chapter—14 ECOSYSTEM

Very Short Answer Type Questions

1. Name an organism found as secondary carnivore in an aquatic ecosystem.
Ans. Cat fish/ Water Snake.
2. What does the base tier of the ecological pyramid represent?
Ans. Producers
3. Under what conditions would a particular stage in the process of succession revert back to an earlier stage.
Ans. Natural or anthropogenic disturbance like fire and deforestation.
4. Arrange the following as observed in vertical stratification in a forest : Grass, Shrubby plants, Teak, *Amaranthus*.
Ans. Grass, *Amaranthus*, Shrubby plants, Teak.
5. Name an omnivore which occurs in both grazing food chain and decomposer food chain.
Ans. Crow / Sparrow
6. Justify the pitcher plant as a producer.
Ans. It is green, chlorophyllous and manufactures food through photosynthesis.
7. Name any two organisms which can occupy more than one trophic level in an ecosystem.
Ans. Man, Crow / Sparrow.
8. In the north-east region of India, during the process of jhum cultivation, forests are cleared by burning and left for regrowth after a year of cultivation. How would you explain the regrowth of forest in ecological term?
Ans. Secondary succession.
9. Climax stage is achieved quickly in secondary succession as compared to primary succession. Why ?
Ans. (i) Soil or substratum is already present while in primary succession it is formed from a bare area. (ii) Propagules of some plants persist in the soil and sprout whenever conditions become favourable.
10. Among bryophytes, lichens and fern which one is pioneer species in xeric succession?
Ans. Lichen
11. What is the ultimate source of energy for the ecosystems?
Ans. Solar radiations
12. Is the common edible mushroom an autotroph or heterotroph?
Ans. Heterotroph.
13. Why are oceans least productive?
Ans. (i) Deficiency of nutrients like nitrogen. (ii) Reduced availability of light in deeper layers of water.

14. Why is the rate of assimilation of energy at the herbivore level called secondary productivity?

Ans. Biomass formed at the producer level is called primary productivity. Rate of assimilation of primary productivity at the herbivore level is, therefore, called secondary productivity.

15. Why are nutrient cycles in nature called biogeochemical cycles?

Ans. Nutrient cycles are called biogeochemical cycles as they circulate nutrients between living beings and abiotic components of earth.

16. Give any two examples of Xerarch succession.

Ans. Sand, bare rock.

17. Define Self Sustainability.

Ans. Self sustainability is the ability to maintain itself indefinitely in stable, functional and viable state as in case of ecosystems due to regular availability of inputs, presence of biocontrols and other self regulations at various levels.

18. Given is a figure of an ecosystem. Answer the following questions.

(i) What type of ecosystem is shown in the figure.

(ii) Name any plant that is characteristic of such ecosystem.

Ans. (i) Desert ecosystem ; (ii) *Capparis decidua* / *Calotropis* / *Aerua*



19. What is common to earthworm, mushroom, soil mites and dung beetle in an ecosystem.

Ans. They are organisms involved in decomposition of organic remains.

Short Answer Type Questions

1. Organisms at a higher trophic level have less energy available. Comment.

Ans. Only 10% of energy passes from one trophic level to the next (10% law). 100 kcal available at producer level retains only 10 kcal of energy at herbivore level, 1.0 kcal at primary carnivore level and only 0.1 kcal at secondary carnivore level. So very less energy becomes available at higher trophic levels.

2. The number of trophic levels in an ecosystem are limited. Comment.

Ans. As only 10% of energy passes from lower to higher trophic level, some 0.1% energy reaches at the fourth trophic level (secondary carnivore). It will be very little (0.01%) at the fifth trophic level. Such highly reduced energy availability cannot sustain any trophic level. Therefore, the number of trophic levels are limited in an ecosystem.

3. Is an aquarium a complete ecosystem?

Ans. Small aquarium having fish only is an **incomplete ecosystem** as it requires regular supply of food, aeration and cleaning. A large aquarium can be made complete if it contains sufficient number of aquatic plants, small animals and decomposers. Even this one requires cleaning at intervals.

4. What could be the reason for the faster rate of decomposition in the tropics?

Ans. Rate of decomposition depends upon soil moisture and temperature (optimum 25°–30°C). Tropics have not and humid climate most suitable for decomposer organisms for speedy decomposition.

5. Human activities interfere with carbon cycle. List any two such activities.

Ans. Human activities are adding CO₂ in the atmosphere due to (i) Increased consumption of fossil fuels that adds CO₂ into atmosphere. (ii) Deforestation that causes reduced carbon assimilation.

6. **Flow of energy through various trophic levels in an ecosystem is unidirectional and noncyclic. Explain.**

Ans. Energy as contained in food passes from lower trophic level to higher trophic level. It does not move in the reverse direction. At energy step of its transfer, 90% of the energy is dissipated as heat and only 10% reaches the higher trophic level. Because of unidirectional movement of food from lower to higher trophic level, the flow of energy is unidirectional. It does not circulate as it is ultimately dissipated as heat.

7. **Apart from plants and animals, microbes form a permanent biotic component in an ecosystem. While plants have been referred to as autotrophs and animals as heterotrophs, what are microbes referred to as? How do the microbes fulfil their energy requirements?**

Ans. Microbes are heterotrophs and saprotrophs. They obtain their requirement of energy by feeding on organic remains through the process of decomposition.

8. **Poaching of tiger is a burning issue in to-days world. What implication would this activity have on the functioning of the ecosystem of which the tigers are an integral part?**

Ans. Poaching or killing of tigers disturbs the biocontrol operating in the ecosystem. Number of herbivores will increase. Increased number of herbivores will cause rapid destruction of vegetation. This will expose the soil to run off water and winds.

9. **In relation to energy transfer in ecosystem, explain the statement "10 kg of deer's meat is equivalent to 1 kg of lion's flesh".**

Ans. Passage of food energy from lower trophic level to higher trophic level follows 10% law. The rest of the energy is dissipated. Lion feeds on deer (lower trophic level). So 10 kg of meat of deer will form only 1 kg of lion's flesh. The rest of the food energy present in deer's meat is wasted and dissipated.

10. **Primary productivity varies from ecosystem to ecosystem. Explain.**

Ans. Primary productivity depends upon the plant species, their photosynthetic potential, soil, climate and other environmental factors of an ecosystem. They are seldom similar in different ecosystems. Therefore, primary productivity varies from ecosystem to ecosystem.

11. **Sometimes due to biotic/abiotic factor the community remains in a particular seral stage (pre-climax) without reaching climax. Do you agree with this statement. If yes, give a suitable example.**

Ans. It is possible. A constant disturbance caused to a biotic or abiotic factor can arrest succession and keep the community in a pre-climax seral stage. The factors contributing to such a situation include summer season forest fires, overgrazing, loose substratum resulting in frequent landslides, changes in soil characteristics like salinity or acidity.

12. **What is an incomplete ecosystem? Explain with the help of suitable example.**

Ans. An ecosystem deficient in one or more regulating biotic or abiotic factors which is unable to sustain itself is called incomplete ecosystem. Absence of producers in an aquarium or aphotic region of ocean make the ecosystem incomplete.

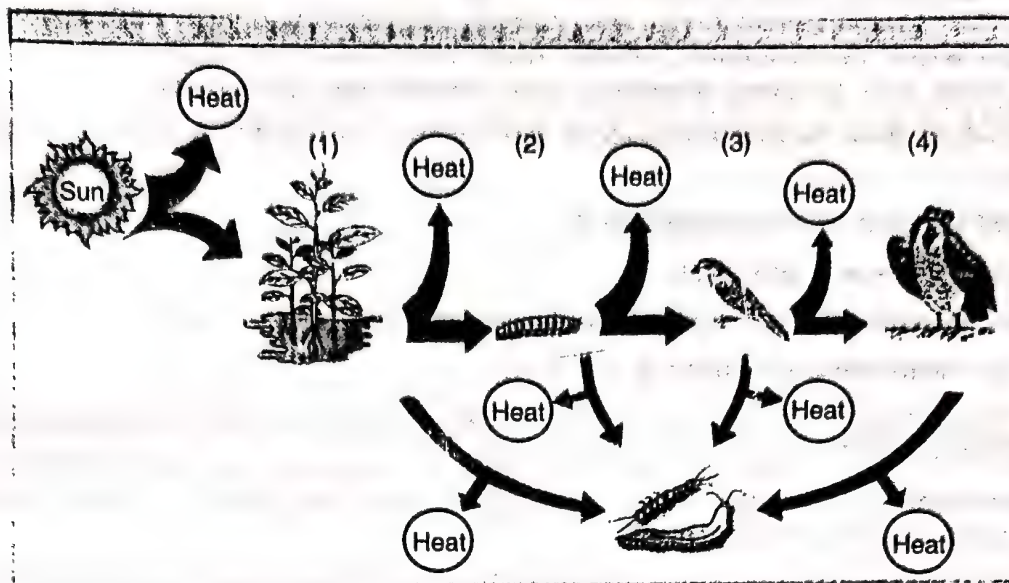
13. **What are short comings of ecological pyramids in the study of ecosystem?**

Ans. Ecological pyramids do not give complete picture of the ecosystem. (i) Ecological pyramids are based on simple food chains. They do not account for food webs where a species may belong to more than one trophic level and function as part of many food chains. (ii) The pyramids do not consider the role of saprophytes in the ecosystem though they are very important in sustaining the ecosystem.

14. **How do you distinguish between humification and mineralisation?**

Ans. Humification is a process of decomposition of organic matter in which a partially decomposed amorphous matter called humus is formed. Mineralisation is the release of inorganic nutrients (minerals and nonminerals) from the decomposing organic matter. They become available for recirculation through absorption by plants.

- 15 Fill in the trophic levels (1, 2, 3 and 4) in the boxes provided in the figure.



- Ans. (1) Producers (2) Herbivores (3) Primary carnivores (4) Secondary or top carnivores.
16. The rate of decomposition of detritus is affected by the abiotic factors like availability of oxygen, pH of soil substratum, temperature, etc. Discuss.
- Ans. Decomposition of detritus is carried out by microorganisms. Type and rate of growth as well as activity of microorganisms are affected by availability of aeration, pH and temperature. (i) **Availability of oxygen** will determine aerobic and anaerobic type of decomposers. Anaerobic decomposers carry out partial or incomplete decomposition. Aerobic decomposers do so completely. (ii) **pH** of the medium shall decide the acidophilic, neutrophilic or basophilic nature of microorganisms and the type of their activity. (iii) **Temperature** determines the rate of decomposition as both microorganisms and their exoenzymes released for decomposition show temperature related activity.

Long Answer Type Questions

- A farmer harvests his crop and expresses his harvest in three different ways.
 - I have harvested 10 quintals of wheat.
 - I have harvested 10 quintals of wheat today in one acre of land.
 - I have harvested 10 quintals of wheat in one acre of land, 6 months after sowing.
 Do the above statements mean one and the same thing. If your answer is yes, give reasons. And if your answer is 'no' explain the meaning of each expression.
- Justify the following statement in terms of ecosystem dynamics. "Nature tends to increase the gross primary productivity, while man tends to increase the net primary productivity".
- Which of the following ecosystems will be more productive in terms of primary productivity? Justify your answer. A young forest, a natural old forest, a shallow polluted lake, alpine meadow.
- What are the three types of ecological pyramids. What information is conveyed by each pyramid with regard to structure, function and energy in the ecosystem.
- Write a short note on pyramid of numbers and pyramid of biomass.

6. Given below is a list of autotrophs and heterotrophs. With your knowledge about food chain, establish various linkages between the organisms on the principle of 'eating and being eaten'. What is this inter-linkage established known as? Algae, hydrilla, grasshopper, rat, squirrel, crow, maize plant, deer, rabbit, lizard, wolf, snake, peacock, phytoplankton, crustaceans, whale, tiger, lion, sparrow, duck, crane, cockroach, spider, toad, fish, leopard, elephant, goat, *Nymphaea*, *Spirogyra*.
7. "The energy flow in the ecosystem follows the second law of thermodynamics." Explain.
8. What will happen to an ecosystem if:
 - a. All producers are removed;
 - b. All organisms of herbivore level are eliminated; and
 - c. All top carnivore population is removed
9. Give two examples of artificial or man made ecosystems. List the salient features by which they differ from natural ecosystems.
10. The biodiversity increases when one moves from the pioneer to the climax stage. What could be the explanation?
11. What is a biogeochemical cycle. What is the role of the reservoir in a biogeochemical cycle. Give an example of a sedimentary cycle with reservoir located in earth's crust.
12. What will be the P/R ratio of a climax community and a pioneer community. What explanation could you offer for the changes seen in P/R ratio of a pioneer community and the climax community.

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

Chapter—15

BIODIVERSITY AND CONSERVATION

Very Short Answer Type Questions

1. **What are characteristics that make a community stable ?**
Ans. Stability of an ecosystem is controlled by (i) Carrying capacity, (ii) Recycling of wastes, (iii) Density related self regulation and (iv) Feed back system.
2. **What could have triggered mass extinctions of species in the past ?**
Ans. Glaciation, melting of snow, eruption of large volcanoes, earthquakes, movement of continents, large meteorites falling on earth, drought, etc. could have triggered mass extinctions.
3. **What accounts for the greater ecological diversity of India ?**
Ans. India has high ecological diversity due to variety of topography, soil types, climates, rainfall zones, sea coasts, islands, etc. Ten well demarcated biogeographical zones with different biota occur in India.
4. **According to David Tilman, greater the diversity, greater is the primary productivity. Can you think of a very low diversity man-made ecosystem that has high productivity?**
Ans. Yes. Agriculture is man-made low diversity ecosystem that has high productivity, e.g., wheat field, paddy field. Monoculture is often practised here.
5. **What does 'Red' indicate in the IUCN Red List (2004) ?**
Ans. 'Red' being a sign of danger, is used by IUCN for those species which are under threat of extinction to various degrees.
6. **Explain as to how protection of biodiversity hot spots alone can reduce upto 30% of the current rate of species extinction.**
Ans. Hot spots are areas rich in endemic species which are under great threat due to human activity. They occupy only 2% of total area but contain about 25% of species and 25% of world population. Threat of their extinction is, therefore, very high. Protection of hot spot biodiversity will naturally reduce the current rate of species extinction by over 30%.
7. **What is the difference between endemic and exotic species ?**
Ans. **Endemic species** is the one which is restricted to a particular region and is not found elsewhere, e.g., Lion Tailed Macaque. **Exotic species** is the one which has been brought from outside and introduced in a local area, e.g., *Eucalyptus*.
8. **How does species diversity differ from ecological diversity ?**
Ans. **Species diversity** is the occurrence of variety and abundance of species in a community while **ecological diversity** is the occurrence of different ecosystems and communities in a geographical area.
9. **Why is genetic variation important in the plant *Rauwolfia vomitoria* ?**
Ans. It results in differences in the potency and concentration of drug **reserpine** in the plant *Rauwolfia vomitoria* found in different regions of Himalaya.
10. **What is Red Data Book ?**
Ans. Red Data Book or Red List is a catalogue of species under varied degree of threat of extinction which is issued by IUCN from time to time to alert ecologists for their protection.

11. Define gene pool.

Ans. Gene pool is the sum total of all the genes and their alleles present in an interbreeding population.

12. What does the term "frugivorous" mean?

Ans. Fruit eating.

13. What is expanded form of IUCN?

Ans. International Union for Conservation of Nature and Natural Resources.

14. Define the terms (i) Bioprospecting and (ii) Endemism.

Ans. **Bioprospecting.** Exploiting molecular, genetic and species level biodiversity for finding out products of economic importance.

Endemism. The degree of restriction of flora and fauna to a particular area is called endemism.

15. What is common to the species shown in Figures A and B?



A



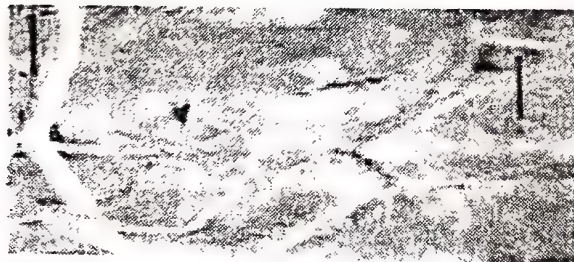
B

Ans. Both are invasive weed species.

16. What is common to species shown in Figures A and B?



A



B

Ans. Both are keystone species.

Short Answer Type Questions

1. How is the presently occurring species extinction different from the earlier mass extinction?

Ans. Earlier species extinction was due to natural causes. Present day species extinction is mostly anthropogenic.

2. Of the four major causes for the loss of biodiversity (alien species invasion, habitat loss and fragmentation, over-exploitation and co-extinctions), which according to you is the major cause for the loss of biodiversity? Give reasons in support.

- Ans.** Habitat loss and fragmentation is the major cause of loss of biodiversity. All the endemic species of the area are the first to become extinct with the loss of habitat. Habitat fragmentation exposes several species of the interior to the external disturbances and suffer loss in number. Reduction of number also occurs in case of other species.
- 3. Discuss one example, based on your day to day observations, showing how loss of one species may lead to the extinction of another.**
- Ans.** *Pronuba yuccasella* depends for its survival on *Yucca* while the latter depends on *Pronuba* for pollination. Extinction of one will naturally cause extinction of the other.
- 4. A species-area curve is drawn by plotting the number of species against the area. How is it that when a very large area is considered the slope is steeper than that for smaller area?**
- Ans.** The regression coefficient is 0.1—0.2 for smaller area and 0.6—1.2 for a large area. Therefore, the slope is steeper for larger area.
- 5. Is it possible that productivity and diversity of natural community remain constant over a time period of, say one hundred years?**
- Ans.** Yes. Climax communities do not change in productivity as well diversity over long period of time unless and until there are drastic changes in climate or human interference.
- 6. There is greater biodiversity in tropical / subtropical regions than in temperate region. Explain.**
- Ans.** See answer to NCERT question 3 of Elementary Biology.
- 7. Why are conventional methods not suitable for the biodiversity of bacteria.**
- Ans.** Biodiversity of bacteria can be assessed only through study of their morphological, biochemical and other specific characteristics. However, many bacteria are not culturable in laboratory under normal conditions. Therefore, conventional methods are not suitable for biodiversity study of bacteria.
- 8. What criteria should one use in categorising a species as threatened?**
- Ans.** A threatened species is one which is unable to realise its full biotic potential and is, therefore, liable to become extinct. The inability of realising full biotic potential is due to (i) Depletion of food, (ii) Habitat deterioration, (iii) Over-exploitation, (iv) Alien species.
- 9. What could be possible explanation for greater vulnerability of amphibians to extinction as compared to other animal groups?**
- Ans.** Amphibians require wetlands for their survival as they pass a part of their life cycle in water. However, wetlands are filled up by humans to create more land. Amphibians dependent on those wetlands get killed.
- 10. How do scientists extrapolate the total number of species on Earth?**
- Ans.** See NCERT Question No. 2 in Elementary Biology.
- 11. Humans benefit from diversity of life. Give two examples.**
- Ans.** Biodiversity provides us with several benefits. The two examples are “
- (i) **Food.** All food we eat comes from plants and animals -- cereals, pulses, fruits, vegetables, milk, eggs, meat.
- (ii) **Industrial Products.** A number of industrial raw materials come from organisms -- tannins, dyes, resins, lubricants, perfumes, paper, rubber, lac.
- 12. List any two major causes, other than anthropogenic causes, of the loss of biodiversity.**
- Ans.** 1. **Natural or Background Extinction.** Species with small population are always in danger of extinction due to natural causes like inbreeding depression, increased number of predators, development of more competitive species and environmental fluctuations like severe drought, severe winter, harsh summer, excess rain, floods, etc.
2. **Mass Extinction.** They occur due to drastic changes on earth like glaciation, volcanoes, earthquakes, movement of tectonic plates, meteorite fall, etc.

13. What is an endangered species ? Give an example of an endangered plant and animal species.

Ans. **Endangered species.** It is a species that is facing a high risk of extinction in the wild in the near future due to decrease in its habitat, excessive predation or poaching.

1. *Bentinckia nicobarica* (Nicobar Palm) and 2. *Asinus hemionus khur* (Asian Wild Ass).

14. What are sacred groves and their role in biodiversity conservation ?

Ans. See NCERT Question No. 7 in Elementary Biology.

15. Suggest a place where one can go to study coral reefs, mangrove vegetation and estuaries.

Ans. Sea shore in a tropical area like Andaman, Kerala coast.

16. Is it true that there is more solar energy available in the tropics ? Explain.

Ans. Sun rays fall vertically over the tropics while they fall obliquely elsewhere. The length of day and night is the same in tropics. It is lesser day hours and longer night hours elsewhere. Therefore, more solar energy is available over tropics than elsewhere.

Long Answer Type Questions

1. Elaborate how invasion by an alien species reduces the species diversity of an area.
2. How can you, as an individual, prevent the loss of biodiversity?
3. Can you think of a scientific explanation, besides analogy used by Paul Ehrlich, for the direct relationship between diversity and stability of an ecosystem?
4. Though the conflict between humans and wildlife started with the evolution of man, the intensity of conflict has increased due to the activities of modern man. Justify your answer with suitable examples.
5. What is an ecosystem service? List any four important ecosystem services provided by the natural ecosystems. Are you in favour or against levying a charge on the service provided by the ecosystem?
6. Describe the consumptive use value of biodiversity as food, drugs and medicines, fuel and fiber with suitable examples.
7. Species diversity decreases as we move away from the equator towards the poles. What could be the possible reasons?
8. Explain briefly the 'rivet popper hypothesis' of Paul Ehrlich.
9. The relation between species richness and area for a wide variety of taxa turns out to be a rectangular hyperbola. Give a brief explanation.

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

Chapter—16

ENVIRONMENTAL ISSUES

Very Short Answer Type Questions

1. **Use of lead-free petrol or diesel is recommended to reduce the pollutants emitted by automobiles. What role does lead play?**
Ans. Lead was previously added to petrol and diesel as antiknock agent.
2. **In which year was the Air (Prevention and Control of Pollution) Act amended to include noise as air pollution.**
Ans. 1987
3. **Name the city in our country where the entire public road transport runs on CNG.**
Ans. Delhi
4. **It is a common practice to undertake desilting of the overhead water tanks. What is the possible source of silt that gets deposited in the water tanks.**
Ans. Soil particles that come along with water from its source.
5. **What is cultural eutrophication?**
Ans. It is human aided nutrient enrichment of water body due to passage of fertilizer rich run off from agricultural fields, treated sewage water and industrial effluents.
6. **List any two adverse effects of particulate matter on human health.**
Ans. (i) Bronchial asthma and chronic bronchitis (ii) Pneumoconiosis.
7. **What is the raw material for polyblend?**
Ans. Waste polythene and other plastic.
8. **Blends of polyblend and bitumen, when used help to increase road life by a factor of three. What is the reason?**
Ans. Increased cohesion and enhanced water repelling property.
9. **Mention any two examples of plants used as wind breakers in the agricultural fields.**
Ans. *Zizyphus*, *Margosa*, *Robinia*, *Mulberry*, *Thevetia*
10. **Name an industry which can cause both air and thermal pollution as well as eutrophication.**
Ans. Fertilizer industry.
11. **What is an algal bloom?**
Ans. The excess growth of planktonic algae like cyanobacteria that causes colouration of water is called algal bloom.
12. **What do you understand by biomagnification?**
Ans. It is increase in the concentration of a persistent chemical (like DDT) with the rise in trophic level.
13. **What are the three major kinds of impurities in domestic waste water?**
Ans. (i) Pathogens ; (ii) Faecal matter ; (iii) Grit (sand, silt, clay and other solid particles).

- 14. What is reforestation.**
Ans. It is development of a forest in an area which has been denuded or degraded in the past.
- 15. What is the best solution for the treatment of electronic wastes?**
Ans. Dumping deep in landfills after shredding or incineration and detoxifying the fumes before release.

Short Answer Type Questions

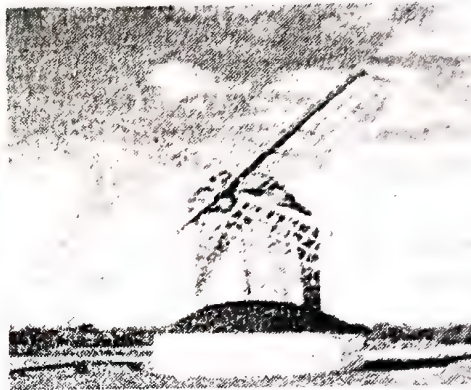
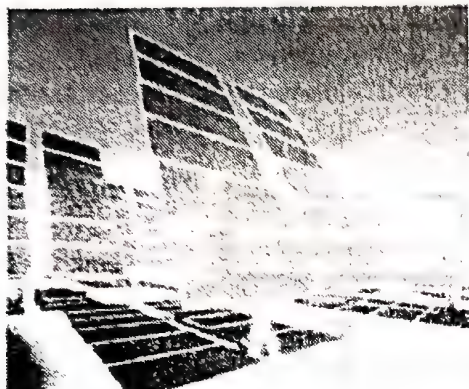
- 1. Is it true that carpets and curtains/drapes placed on the floor or wall surfaces can reduce noise level? Explain briefly.**
Ans. Yes. Carpets, curtains/drapes form a barrier between the source of sound and ourselves by their absorbance and reflectivity. They are, therefore, called acoustic furnishings.
- 2. What is hybrid vehicle technology? Explain its advantages with a suitable example.**
Ans. Hybrid vehicle technology is the use of more than one type of energy/fuel source for the vehicles. In one type CNG is used along with petrol/diesel. In another type petrol and long life highly efficient batteries are used.
Advantages — (i) Less consumption of petrol (ii) Less pollution.
- 3. Is it true that if the dissolved oxygen level drops to zero, the water will become septic. Give an example which could lower the dissolved oxygen content of an aquatic body.**
Ans. Yes. Water becomes septic due to the absence of aerobic decomposition and killing of animals. Passage of sewage or organic matter into water body will lower its dissolved oxygen content.
- 4. Name any one green house gas and its possible source of production on a large scale. What are the harmful effects of it?**
Ans. Carbon dioxide. Its level is increasing due to continued combustion of fossil fuels and deforestation.
- 5. It is a common practice to plant trees and shrubs near the boundary walls of buildings. What purpose do they serve ?**
Ans. The plants growing near the boundary wall catch dust particles and absorb pollutant gases. They function as green muffler and reduce sound coming from outside.
- 6. Why has the National Forest Commission of India recommended a relatively larger forest cover for hills than for plains?**
Ans. As per recommendation of National Forest Commission, hills should have a forest cover of 66% (as compared to 33% for plains). A higher and denser forest cover shall (i) Increase absorption and percolation of rain water; (ii) Prevent landslides ; (iii) Decrease run off and hence floods; (iv) Produce permanent springs and rivulets; (v) Moderate the climate.
- 7. How can slash and burn agriculture become environment friendly ?**
Ans. Slash and burn agriculture can become environment friendly if rows of trees and shrubs are left intact while clearing the area for cultivation. This will prevent soil erosion and invasion of weeds. There will be quicker recovery of forest after the area is abandoned.
- 8. What is the main idea behind "Joint Forest Management Concept" introduced by Government of India.**
Ans. It is government-private entrepreneurship for upkeep of forests. The forest department prepares the plan, procures saplings and equipment for planting and plant protection. The locals take care of the plants till they become mature. For this they get honorarium and share in plant products. This sort of management provides livelihood to locals and protection to plants against stealing and illegal felling.
- 9. What do you understand by snow blindness?**
Ans. Snow blindness is a temporary blindness caused by inflammation of cornea due to absorption of UV-B radiations. It is accompanied by photoburning and dimming of eye

sight. Cataract develops. Regular exposure to UV-B radiations causes a permanent damage to cornea resulting in blindness.

10. How has DDT caused decline in bird population?

Ans. DDT is a persistent pollutant. It undergoes biomagnification so that its concentration rises with each trophic level to over a million times in fish eating birds, e.g., Bald Eagle (25 ppm from 0.003 ppb in water). High concentration of DDT in the body of bird causes liver cirrhosis, cerebral haemorrhage and malfunctioning of sex hormones. Calcium metabolism is disturbed. It results in thinning of egg shells, their premature breaking and death of embryo. As a result there was decline in bird population.

11. Observe the figures A and B and answer the following questions.



(i) The power generation by the above two methods is nonpolluting — True/False.

(ii) List any two applications of solar energy.

(iii) What is photovoltaic cell?

Ans. (i) True.

(ii) **Applications of Solar Energy.** (a) Solar cookers; (b) Water heaters ; (iii) Generation of electricity for household appliances.

(iii) **Photovoltaic Cell.** Photovoltaic or solar cell is a semi conductor diode, often made of silicon, which converts light energy into electricity.

Long Answer Type Questions

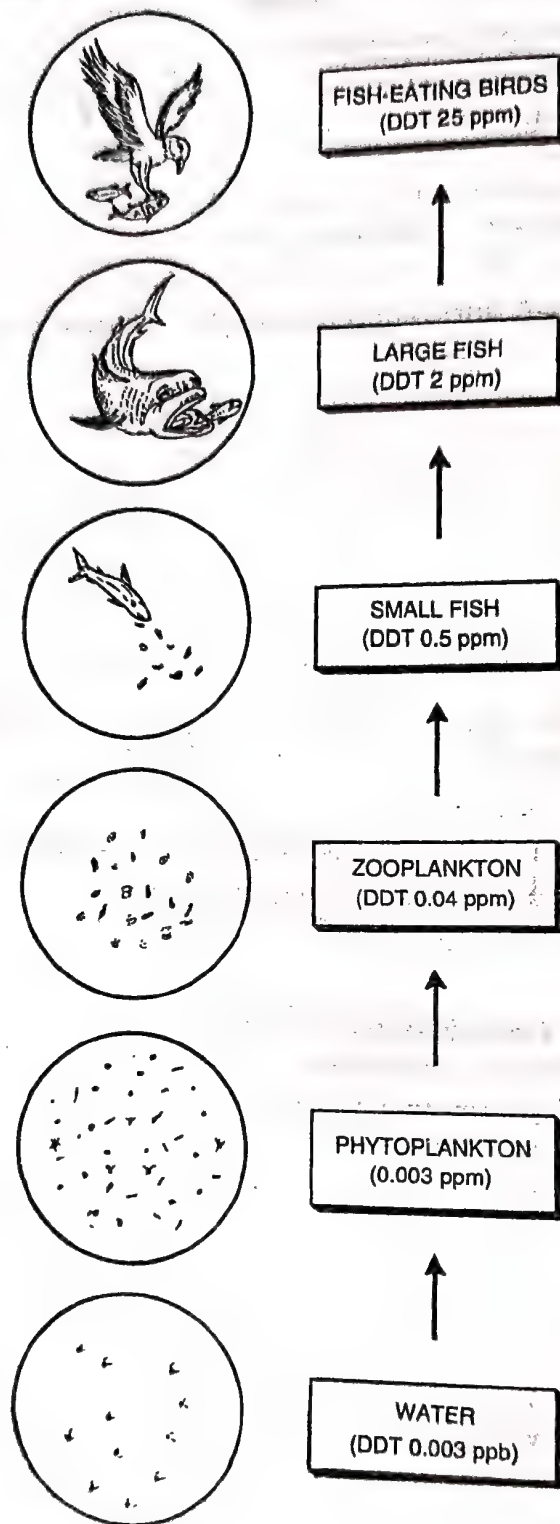
- Write a short note on electronic waste. List the various sources of e- wastes and the problems associated with its disposal.
- What is organic farming? Discuss the benefits of organic farming as a viable practise in the context of developing nations like India.
- Water logging and soil salinity are some of the problems that have come in the wake of the Green Revolution. Discuss their causes and adverse effects to the environment.
- What are multipurpose trees? Give the botanical and local names of any two multipurpose trees known to you and list their uses.
- What are the basic characteristics of a modern landfill site. List any three and also mention the reasons for their use.

Ans. Characteristics of a modern landfill include:

- methods to contain leachate such as lining clay or plastic liners.
- compaction and covering of the waste to prevent it from being blown by wind.
- installation of a landfill gas extraction system to extract the gas for use in generation of power.

6. How does an electrostatic precipitator work?

7. Observe figure and answer the following questions.



- What ecological term is used to describe the DDT accumulation at different trophic levels?
- List any one effect of DDT accumulation on birds.
- Will DDT accumulation lead to eutrophication?
- Does it affect the BOD?
- Name disease caused by accumulation of any heavy metal.

[For Answers to Long Answer Type Questions, Refer to Text — Elementary Biology]

NCERT Exemplar Questions (MCQs)

REPRODUCTION IN ORGANISMS

1. A few statements describing certain features of reproduction are given below
 - i. Gametic fusion takes place
 - ii. Transfer of genetic material takes place
 - iii. Reduction division takes place
 - iv. Progeny have some resemblance with parents

Select the options that are true for both asexual and sexual reproduction from the options given below:

- (a) i and ii
 - (b) ii and iii
 - (c) ii and iv
 - (d) i and iii
2. The term 'clone' cannot be applied to offspring formed by sexual reproduction because
 - (a) Offspring do not possess exact copies of parental DNA
 - (b) DNA of only one parent is copied and passed on to the offspring
 - (c) Offspring are formed at different times
 - (d) DNA of parent and offspring are completely different
3. Asexual method of reproduction by binary fission is common to which of the following ? (i) Some eukaryotes (ii) All eukaryotes (iii) Some prokaryotes (iv) All prokaryotes

Options :

- (a) (i) and (ii)
 - (b) (ii) and (iii)
 - (c) (i) and (iii)
 - (d) (iii) and (iv)
4. A few statements with regard to sexual reproduction are given below:
 - i. Sexual reproduction does not always require two individuals
 - ii. Sexual reproduction generally involves gametic fusion
 - iii. Meiosis never occurs during sexual reproduction
 - iv. External fertilisation is rule during sexual reproduction

Choose the correct statements from the options below

- (a) i and iv
 - (b) i and ii
 - (c) ii and iii
 - (d) i and iv
5. A multicellular, filamentous alga exhibits a type of sexual life cycle in which the mei-

otic division occurs after the formation of zygote. The adult filament of this alga has

- (a) haploid vegetative cells and diploid gametangia
 - (b) diploid vegetative cells and diploid gametangia
 - (c) diploid vegetative cells and haploid gametangia
 - (d) haploid vegetative cells and haploid gametangia
6. The male gametes of rice plant have 12 chromosomes in their nucleus. The chromosome number in the female gamete, zygote and the cells of the seedling will be, respectively,
 - (a) 12, 24, 12
 - (b) 24, 12, 12
 - (c) 12, 24, 24
 - (d) 24, 12, 24
7. Given below are a few statements related to external fertilization, Choose the correct statements.
 - i. The male and female gametes are formed and released simultaneously
 - ii. Only a few gametes are released into the medium
 - iii. Water is the medium in a majority of organisms exhibiting external fertilization
 - iv. Offspring formed as a result of external fertilization have better chance of survival than those formed inside an organism
 - (a) iii and iv
 - (b) i and iii
 - (c) ii and iv
 - (d) i and iv
8. The statements given below describe certain features that are observed in the pistil of flowers
 - i. Pistil may have many carpels
 - ii. Each carpel may have more than one ovule
 - iii. Each carpel has only one ovule
 - iv. Pistil have only one carpel

Choose the statements that are true from the options below

 - (a) i and ii
 - (b) i and iii
 - (c) ii and iv
 - (d) iii and iv
9. Which of the following situations correctly describe the similarity between an angiosperm egg and a human egg?
 - i. Eggs of both are formed only once in a lifetime

- ii. Both the angiosperm egg and human egg are stationary
- iii. Both the angiosperm egg and human egg are motile and transported
- iv. Syngamy in both results in the formation of zygote

Choose the correct answer from the options given below

- (a) ii and iv
- (b) iv only
- (c) iii and iv
- (d) i and iv

[Hint: The term 'stationary' in statement (ii) means not transported, which is true for angiosperm egg but false for human ovum.]

10. Appearance of vegetative propagules from the nodes of plants such as sugarcane and ginger is mainly because
- (a) nodes are shorter than internodes
 - (b) nodes have meristematic cells
 - (c) nodes are located near the soil
 - (d) nodes have non-photosynthetic cells
11. Which of the following statements, support the view that elaborate sexual reproductive process appeared much later in the organic evolution.
- i. Lower groups of organisms have simpler body design
 - ii. Asexual reproduction is common in lower groups
 - iii. Asexual reproduction is common in higher groups of organisms
 - iv. The high incidence of sexual reproduction in angiosperms and vertebrates

Choose the correct answer from the options given below:

- (a) (i), (ii) & (iii)
- (b) (i), (iii) & (iv)
- (c) (i), (ii) & (iv)
- (d) (ii), (iii) & (iv)

12. Offspring formed by sexual reproduction exhibit more variation than those formed by asexual reproduction because
- (a) sexual reproduction is a lengthy process
 - (b) gametes of parents have qualitatively different genetic composition
 - (c) genetic material comes from parents of two different species
 - (d) greater amount of DNA is involved in sexual reproduction.
13. Choose the correct statement from amongst the following.
- (a) Dioecious (hermaphrodite) organisms are seen only in animals

- (b) Dioecious organisms are seen only in plants
- (c) Dioecious organisms are seen in both plants and animals
- (d) Dioecious organisms are seen only in vertebrates

14. There is no natural death in single celled organisms like *Amoeba* and bacteria because
- (a) they cannot reproduce sexually
 - (b) they reproduce by binary fission
 - (c) parental body is distributed among the offspring
 - (d) they are microscopic
15. There are various types of reproduction. The type of reproduction adopted by an organism depends on
- (a) the habitat and morphology of the organism
 - (b) morphology of the organism
 - (c) morphology and physiology of the organism
 - (d) the organism's habitat, physiology and genetic makeup
16. Identify the incorrect statement.
- (a) In asexual reproduction, the offspring produced are morphologically and genetically identical to the parent
 - (b) Zoospores are sexual reproductive structures
 - (c) In asexual reproduction, a single parent produces offspring with or without the formation of gametes
 - (d) Conidia are asexual structures in *Penicillium*
17. Which of the following is a post-fertilisation event in flowering plants?
- (a) Transfer of pollen grains
 - (b) Embryo development
 - (c) Formation of flower
 - (d) Formation of pollen grains
18. The number of chromosomes in the shoot tip cells of a maize plant is 20. The number of chromosomes in the microspore mother cells of the same plant shall be:
- (a) 20
 - (b) 10
 - (c) 40
 - (d) 15

ANSWERS

- | | | | | | |
|---------|---------|---------|---------|---------|---------|
| 1. (c) | 2. (a) | 3. (c) | 4. (b) | 5. (d) | 6. (c) |
| 7. (b) | 8. (a) | 9. (b) | 10. (b) | 11. (c) | 12. (b) |
| 13. (c) | 14. (c) | 15. (d) | 16. (b) | 17. (b) | 18. (a) |

SEXUAL REPRODUCTION IN FLOWERING PLANTS

1. Among the terms listed below, those that are not technically correct names for a floral whorl are
 - i. Androeceum
 - ii. Carpel
 - iii. Corolla
 - iv. Sepal(a) i and iv (b) iii and iv
(c) ii and iv (d) i and ii
2. Embryo sac is to ovule as _____ is to an anther
 - (a) stamen
 - (b) filament
 - (c) pollen grain
 - (d) androeceum
3. In a typical complete, bisexual and hypogynous flower the arrangement of floral whorl on the thalamus from the outermost to the innermost is
 - (a) calyx, corolla, androeceum and gynoecium
 - (b) calyx, corolla, gynoecium and androeceum
 - (c) gynoecium, androeceum, corolla and calyx
 - (d) androeceum, gynoecium, corolla and calyx
4. A dicotyledonous plant bears flowers but never produces fruits and seeds. The most probable cause for the above situation is
 - (a) plant is dioecious and bears only pistillate flowers
 - (b) plant is dioecious and bears both pistillate and staminate flowers
 - (c) plant is monoecious
 - (d) plant is dioecious and bears only staminate flowers
5. The outermost and innermost wall layers of microsporangium in an anther are respectively
 - (a) endothecium and tapetum
 - (b) epidermis and endodermis
 - (c) epidermis and middle layer
 - (d) epidermis and tapetum
6. During microsporogenesis, meiosis occurs in
 - (a) endothecium
 - (b) microspore mother cells
 - (c) microspore tetrads
 - (d) pollen grains
7. From among the sets of terms given below, identify those that are associated with the gynoecium.
 - (a) Ovule, stigma, ovary, embryo sac, tapetum
 - (b) Ovule, stamen, ovary, embryo sac
8. Starting from the innermost part, the correct sequence of parts in an ovule are,
 - (a) egg, nucellus, embryo sac, integument
 - (b) egg, embryo sac, nucellus, integument
 - (c) embryo sac, nucellus, integument, egg
 - (d) egg, integument, embryo sac, nucellus
9. From the statements given below choose the option that are true for a typical female gametophyte of a flowering plant
 - i. It is 8-nucleate and 7-celled at maturity
 - ii. It is free-nuclear during the development
 - iii. It is situated inside the integument but outside the nucellus
 - iv. It has an egg apparatus situated at the chalazal end
 - (a) i and iv
 - (b) ii and iii
 - (c) i and ii
 - (d) ii and iv
10. Autogamy can occur in a chasmogamous flower if
 - (a) pollen matures before maturity of ovule
 - (b) ovules mature before maturity of pollen
 - (c) both pollen and ovules mature simultaneously
 - (d) both anther and stigma are of equal lengths
11. Choose the correct statement from the following.
 - (a) Cleistogamous flowers always exhibit autogamy
 - (b) Chasmogamous flowers always exhibit geitonogamy
 - (c) Cleistogamous flowers exhibit both autogamy and geitonogamy
 - (d) Chasmogamous flowers never exhibit autogamy
12. A particular species of plant produces light, non-sticky pollen in large numbers and its stigmas are long and feathery. These modifications facilitate pollination by
 - (a) insects
 - (b) water
 - (c) wind
 - (d) animals

13. From among the situations given below, choose the one that prevents both autogamy and geitonogamy.
- Monoecious plant bearing unisexual flowers
 - Dioecious plant bearing only male or female flowers
 - Monoecious plant with bisexual flowers
 - Dioecious plant with bisexual flowers
14. In a fertilized embryo sac, the haploid, diploid and triploid structures are
- synergid, zygote and primary endosperm nucleus
 - synergid, antipodal and polar nuclei
 - antipodal, synergid and primary endosperm nucleus
 - synergid, polar nuclei and zygote
15. In an embryo sac, the cells that degenerate after fertilisation are
- synergids and primary endosperm cell
 - synergids and antipodals
 - antipodals and primary endosperm cell
 - egg and antipodals.
16. While planning for an artificial hybridization programme involving dioecious plants, which of the following steps would not be relevant?
- Bagging of female flower
 - Dusting of pollen on stigma
 - Emasculation
 - Collection of pollen
17. In the embryos of a typical dicot and a grass, true homologous structures are
- coleorhiza and coleoptile
 - coleoptile and scutellum
 - cotyledons and scutellum
 - hypocotyl and radicle.
18. The phenomenon observed in some plants wherein parts of the sexual apparatus is used for forming embryos without fertilisation is called
- parthenocarpy
 - apomixis
 - vegetative propagation
 - sexual reproduction
19. In a flower, if the megaspore mother cell forms megaspores without undergoing meiosis and if one of the megaspores develops into an embryo sac, its nuclei would be
- haploid
 - diploid
 - a few haploid and a few diploid
 - with varying ploidy
20. The phenomenon wherein, the ovary develops into a fruit without fertilisation is called
- parthenocarpy
 - apomixis
 - asexual reproduction
 - sexual reproduction

ANSWERS

- | | | | | | |
|---------|---------|---------|---------|---------|---------|
| 1. (c) | 2. (c) | 3. (a) | 4. (d) | 5. (d) | 6. (b) |
| 7. (a) | 8. (b) | 9. (c) | 10. (c) | 11. (a) | 12. (c) |
| 13. (b) | 14. (a) | 15. (b) | 16. (c) | 17. (c) | 18. (b) |
| 19. (b) | 20. (a) | | | | |

HUMAN REPRODUCTION

1. Choose the incorrect statement from the following.
- In birds and mammals internal fertilisation takes place
 - Colostrum contains antibodies and nutrients
 - Polyspermy in mammals is prevented by the chemical changes in the egg surface
 - In the human female implantation occurs almost seven days after fertilisation
2. Identify the correct statement from the following.
- High levels of estrogen triggers the ovulatory surge
 - Oogonial cells start to proliferate and give rise to functional ova in regular cycles from puberty onwards.
 - Sperms released from seminiferous tubules are highly motile
 - Progesterone level is high during the post ovulatory phase of menstrual cycle
- [Hint: If in statement (a) it was mentioned 'Pre-ovulatory surge of LH' then it would also have been correct.]
3. Spot the odd one out from the following structures with reference to the male reproductive system.
- Rete testis
 - Epididymis
 - Vasa efferentia
 - Isthmus
4. Seminal plasma, the fluid part of semen, is contributed by
- Seminal vesicle
 - Prostate

- iii. Urethra
iv. Bulbourethral gland
- (a) i and ii (b) i, ii and iv
(c) ii, iii and iv (d) i and iv
5. Spermiation is the process of the release of sperms from
(a) Seminiferous tubules
(b) Vas deferens
(c) Epididymis (d) Prostate gland
6. Mature Graafian follicle is generally present in the ovary of a healthy human female around
(a) 5 – 8 day of menstrual cycle
(b) 11 – 17 day of menstrual cycle
(c) 18 – 23 day of menstrual cycle
(d) 24 – 28 day of menstrual cycle
7. Acrosomal reaction of the sperm occurs due to
(a) its contact with zona pellucida of the ova
(b) reactions within the uterine environment of the female
(c) reactions within the epididymal environment of the male
(d) androgens produced in the uterus
8. Which one of the following is not a male accessory gland?
(a) Seminal vesicle (b) Ampulla
(c) Prostate
(d) Bulbourethral gland
9. The immature male germ cell undergoes division to produce sperms by the process of spermatogenesis. Choose the correct one with reference to above.
(a) Spermatogonia have 46 chromosomes and always undergo meiotic cell division
(b) Primary spermatocytes divide by mitotic cell division
(c) Secondary spermatocytes have 23 chromosomes and undergo second meiotic division
(d) Spermatozoa are transformed into spermatids
10. Match between the following representing parts of the sperm and their functions and choose the correct option.

	Col. A		Col. B
A.	Head	i.	Enzymes
B.	Middle piece	ii.	Sperm motility
C.	Acrosome	iii.	Energy
D.	Tail	iv.	Genetic material

Options:

- (a) A-II, B-iv, C-I, D-III
(b) A-iv, B-III, C-I, D-II
(c) A-iv, B-I, C-II, D-III
(d) A-II, B-I, C-III, D-iv
11. Which among the following has 23 chromosomes?
(a) Spermatogonia (b) Zygote
(c) Secondary oocyte (d) Oogonia
12. Match the following and choose the correct options.
- | | |
|--------------------|------------------------------------------------------------|
| A. Trophoblast | i. Embedding of blastocyst in the endometrium |
| B. Cleavage | ii. Group of cells that would differentiate as embryo |
| C. Inner cell mass | iii. Outer layer of blastocyst attached to the endometrium |
| D. Implantation | iv. Mitotic division of zygote |
- (a) A-ii, B-i, C-iii, D-iv
(b) A-iii, B-iv, C-ii, D-i
(c) A-iii, B-iv, C-ii, D-i
(d) A-ii, B-iv, C-iii, D-i
13. Which of the following hormones is not secreted by human placenta?
(a) hCG (b) Estrogens
(c) Progesterone (d) LH
14. The vas deferens receives duct from the seminal vesicle and opens into urethra as
(a) epididymis (b) ejaculatory duct
(c) efferent ductule (d) ureter
15. Urethral meatus refers to the
(a) urinogenital duct
(b) opening of vas deferens into urethra
(c) external opening of the Urinogenital duct
(d) muscles surrounding the urinogenital duct
16. Morula is a developmental stage
(a) between the zygote and blastocyst
(b) between the blastocyst and gastrula
(c) after the implantation
(d) between implantation and parturition

17. The membranous cover of the ovum at ovulation is

- (a) Corona radiata (b) Zona radiata
(c) Zona pellucida (d) Chorion

[Hint: The human ovum is enclosed by two additional egg coats. Inner noncellular zona pellucida which is secreted by the ovum and is made of glycoproteins. It is a primary egg membrane. The second coat is the outer corona radiata, which is formed by the follicle cells of the ovary and is a secondary membrane.]

18. Identify the odd one from the following.

- (a) Labia minora (b) Fimbriae
(c) Infundibulum (d) Isthmus

ANSWERS

1. (c) 2. (d) 3. (d) 4. (b) 5. (a) 6. (b)
7. (a) 8. (b) 9. (c) 10. (b) 11. (c) 12. (b)
13. (d) 14. (b) 15. (c) 16. (a) 17. (a) 18. (a)

REPRODUCTIVE HEALTH

1. The method of directly injecting a sperm into ovum, assisted by reproductive technology is called

- (a) GIFT (b) ZIFT (c) ICSI (d) ET

2. Increased IMR and decreased MMR in a population will

- (a) cause rapid increase in growth rate
(b) result in decline in growth rate
(c) not cause significant change in growth rate
(d) result in an explosive population/exp

3. Intensely lactating mothers do not generally conceive due to the

- (a) suppression of gonadotropins
(b) hyper secretion of gonadotropins
(c) suppression of gametic transport
(d) suppression of fertilisation

4. Sterilisation techniques are generally full proof methods of contraception with least side effects. Yet, this is the last option for the couples because

- i. it is almost irreversible
ii. of the misconception that it will reduce sexual urge/drive
iii. it is a surgical procedure
iv. of lack of sufficient facilities in many parts of the country

Choose the correct option

- (a) i and iii (b) ii and iii
(c) ii and iv (d) i, ii, iii and iv

5. A national level approach to build up a reproductively healthy society was taken up in our country in

- (a) 1950s (b) 1960s (c) 1980s (d) 1990s

6. Emergency contraceptives are effective if used within

- (a) 72 hrs of coitus
(b) 72 hrs of ovulation
(c) 72 hrs of menstruation
(d) 72 hrs of implantation

7. Choose the right one among the statements given below.

- (a) IUDs are generally inserted by the user herself
(b) IUDs increase phagocytosis reaction in the uterus
(c) IUDs suppress gametogenesis
(d) IUDs once inserted need not be replaced

8. Following statements are given regarding MTP. Choose the correct options given below.

- i. MTPs are generally advised during first trimester
ii. MTPs are used as a contraceptive method
iii. MTPs are always surgical
iv. MTPs require the assistance of qualified medical personnel

- (a) ii and iii (b) ii, iii and iv
(c) i and iv (d) i, ii and iii

9. From the sexually transmitted diseases mentioned below, identify the one which does not specifically affect the sex organs.

- (a) Syphilis (b) AIDS
(c) Gonorrhoea (d) Genital warts

10. Condoms are one of the most popular contraceptives because of the following reasons.

- (a) These are effective barriers for insemination
(b) They do not interfere with coital act
(c) These help in reducing the risk of STDs
(d) All of the above

11. Choose the correct statement regarding the ZIFT procedure.

- (a) Ova collected from a female donor are transferred to the fallopian tube to facilitate zygote formation.

- (b) Zygote is collected from a female donor and transferred to the fallopian tube
 (c) Zygote is collected from a female donor and transferred to the uterus
 (d) Ova collected from a female donor and transferred to the uterus

[Hint: In ZIFT, it is not the zygote which is collected from the donor, but the ova is collected and made to fertilise in vitro, then the zygote is transferred to the fallopian tube.]

12. The correct surgical procedure as a contraceptive method is
 (a) ovariectomy (b) hysterectomy
 (c) vasectomy (d) castration
13. Diaphragms are contraceptive devices used by the females. Choose the correct option from the statements given below.
 i. They are introduced into the uterus
 ii. They are placed to cover the cervical region
 iii. They act as physical barriers for sperm entry
 iv. They act as spermicidal agents
 (a) i and ii (b) i and iii
 (c) ii and iii (d) iii and iv

ANSWERS

1. (c) 2. (c) 3. (a) 4. (d) 5. (a) 6. (a)
 7. (b) 8. (c) 9. (b) 10. (d) 11. (b) 12. (c)
 13. (c)

PRINCIPLE OF INHERITANCE AND VARIATION

1. All genes located on the same chromosome
 (a) form different groups depending upon their relative distance
 (b) form one linkage group
 (c) will not form any linkage groups
 (d) form interactive groups that affect the phenotype
2. Conditions of a Karyotype $2n \pm 1$ and $2n \pm 2$ are called
 (a) aneuploidy (b) polyploidy
 (c) allopolyploidy (d) monosomy
3. Distance between the genes and percentage of recombination shows
 (a) a direct relationship
 (b) an inverse relationship
 (c) a parallel relationship
 (d) no relationship
4. If a genetic disease is transferred from a phenotypically normal but carrier female to only some of the male progeny, the disease is
 (a) autosomal dominant
 (b) autosomal recessive
 (c) sex-linked dominant
 (d) sex-linked recessive
5. In sickle cell anaemia glutamic acid is replaced by valine. Which one of the following triplets codes for valine?
 (a) GGG (b) AAG (c) GAA (d) GUG
6. Person having genotype $I^A I^B$ would show the blood group as AB. This is because of
 (a) pleiotropy (b) co-dominance
 (c) segregation (d) incomplete dominance
7. ZZ/ZW type of sex determination is seen in
 (a) Platypus (b) Snails
 (c) Cockroach (d) Peacock
8. Cross between two tall plants resulted in offspring having few dwarf plants. What would be the genotypes of both the parents?
 (a) TT and Tt (b) Tt and Tt
 (c) TT and TT (d) Tt and tt
9. In a dihybrid cross, if you get 9:3:3:1 ratio it denotes that
 (a) the alleles of two genes are interacting with each other
 (b) it is a multigenic inheritance
 (c) it is a case of multiple allelism
 (d) the alleles of two genes are segregating independently.
10. Which of the following will not result in variations among siblings?
 (a) Independent assortment of genes
 (b) Crossing over
 (c) Linkage (d) Mutation
11. Mendel's Law of independent assortment holds good for genes situated on the
 (a) non-homologous chromosomes
 (b) homologous chromosomes
 (c) extra nuclear genetic element
 (d) same chromosome
12. Occasionally, a single gene may express more than one effect. The phenomenon is called
 (a) multiple allelism (b) mosaicism
 (c) pleiotropy (d) polygeny

13. In a certain taxon of insects some have 17 chromosomes and the others have 18 chromosomes. The 17 and 18 chromosome-bearing organisms are

(a) males and females, respectively
(b) females and males, respectively
(c) all males (d) all females

14. The inheritance pattern of a gene over generations among humans is studied by the pedigree analysis. Character studied in the pedigree analysis is equivalent to

(a) quantitative trait (b) Mendelian trait
(c) polygenic trait (d) maternal trait

15. It is said that Mendel proposed that the factor controlling any character is discrete and independent. This proposition was based on the

(a) results of F_3 generation of a cross.
(b) observations that the offspring of a cross made between the plants having two contrasting characters shows only one character without any blending
(c) self pollination of F_1 offsprings
(d) cross pollination of F_1 generation with recessive parent

16. Two genes 'A' and 'B' are linked. In a dihybrid cross involving these two genes, the F_1 heterozygote is crossed with homozygous recessive parental type (aa b(b). What would be the ratio of offspring in the next generation?

(a) 1 : 1 : 1 : 1 (b) 9 : 3 : 3 : 1
(c) 3 : 1 (d) 1 : 1

17. In the F_2 generation of a Mendelian dihybrid cross the number of phenotypes and genotypes are

(a) phenotypes – 4; genotypes – 16
(b) phenotypes – 9; genotypes – 4
(c) phenotypes – 4; genotypes – 8
(d) phenotypes – 4; genotypes – 9

18. Mother and Father of a person with 'O' blood group have 'A' and 'B' blood group respectively. What would be the genotype of both mother and father?

(a) Mother is homozygous for 'A' blood group and father is heterozygous for 'B'
(b) Mother is heterozygous for 'A' blood group and father is homozygous for 'B'
(c) Both mother and father are heterozy-

gous for 'A' and 'B' blood group, respectively

- (d) Both mother and father are homozygous for 'A' and 'B' blood group, respectively

ANSWERS

- | | | | | | |
|---------|---------|---------|---------|---------|---------|
| 1. (b) | 2. (a) | 3. (a) | 4. (d) | 5. (d) | 6. (b) |
| 7. (d) | 8. (b) | 9. (d) | 10. (c) | 11. (a) | 12. (c) |
| 13. (a) | 14. (b) | 15. (b) | 16. (d) | 17. (d) | 18. (c) |

MOLECULAR BASIS OF INHERITANCE

- In a DNA strand the nucleotides are linked together by
 - glycosidic bonds
 - phosphodiester bonds
 - peptide bonds
 - hydrogen bonds
- A nucleoside differs from a nucleotide. It lacks the
 - base
 - sugar
 - phosphate group
 - hydroxyl group
- Both deoxyribose and ribose belong to a class of sugars called
 - trioses
 - hexoses
 - pentoses
 - polysaccharides
- The fact that purine base always paired through hydrogen bonds with a pyrimidine base leads to, in the DNA double helix:
 - the antiparallel nature
 - the semiconservative nature
 - uniform width throughout DNA
 - uniform length in all DNA
- The net electric charge on DNA and histones is
 - both positive
 - both negative
 - negative and positive, respectively
 - zero
- The promoter site and the terminator site for transcription are located at
 - 3' (downstream) end and 5' (upstream) end, respectively of the transcription unit
 - 5' (upstream) end and 3' (downstream) end, respectively of the transcription unit
 - the 5' (upstream) end
 - the 3' (downstream) end

7. Which of the following statements is the most appropriate for sickle cell anaemia?
 - (a) It cannot be treated with iron supplements
 - (b) It is a molecular disease
 - (c) It confers resistance to acquiring malaria
 - (d) All of the above
8. One of the following is true with respect to AUG
 - (a) It codes for methionine only
 - (b) It is also an initiation codon
 - (c) It codes for methionine in both prokaryotes and eukaryotes
 - (d) All of the above
9. The first genetic material could be
 - (a) protein
 - (b) carbohydrates
 - (c) DNA
 - (d) RNA
10. With regard to mature mRNA in eukaryotes
 - (a) exons and introns do not appear in the mature RNA
 - (b) exons appear but introns do not appear in the mature RNA
 - (c) introns appear but exons do not appear in the mature RNA
 - (d) both exons and introns appear in the mature RNA
11. The human chromosome with the highest and least number of genes in them are respectively
 - (a) chromosome 21 and Y
 - (b) chromosome 1 and X
 - (c) chromosome 1 and Y
 - (d) chromosome X and Y
12. Who amongst the following scientists had no contribution in the development of the double helix model for the structure of DNA?
 - (a) Rosalind Franklin
 - (b) Maurice Wilkins
 - (c) Erwin Chargaff
 - (d) Meselson & Stahl
13. DNA is a polymer of nucleotides which are linked to each other by 3' – 5' phosphodiester bond. To prevent polymerisation of nucleotides, which of the following modifications would you choose?
 - (a) Replace purine with pyrimidines
 - (b) Remove/Replace 3' OH group in deoxy ribose
 - (c) Remove/Replace 2' OH group with some other group in deoxy ribose
 - (d) Both ((b) and (c))
14. Discontinuous synthesis of DNA occurs in one strand, because
 - (a) DNA molecule being synthesised is very long
 - (b) DNA dependent DNA polymerase catalyses polymerisation only in one direction (5' 3')
 - (c) It is a more efficient process
 - (d) DNA ligase has to have a role
15. Which of the following steps in transcription is catalysed by RNA polymerase?
 - (a) Initiation
 - (b) Elongation
 - (c) Termination
 - (d) All of the above

[Hint: The RNA polymerase is only capable of catalysing the process of elongation. It associates transiently with initiation factor sigma and termination factor rho to initiate and terminate the transcription respectively.]
16. Control of gene expression takes place at the level of
 - (a) DNA-replication
 - (b) Transcription
 - (c) Translation
 - (d) None of these
17. Regulatory proteins are the accessory proteins that interact with RNA polymerase and affect its role in transcription. Which of the following statements is correct about regulatory protein?
 - (a) They only increase expression
 - (b) They only decrease expression
 - (c) They interact with RNA polymerase but do not affect the expression
 - (d) They can act both as activators and as repressors
18. Which was the last human chromosome to be completely sequenced?
 - (a) Chromosome 1
 - (b) Chromosome 11
 - (c) Chromosome 21
 - (d) Chromosome x
19. Which of the following are the functions of RNA?
 - (a) It is a carrier of genetic information from DNA to ribosomes synthesising polypeptides.
 - (b) It carries amino acids to ribosomes
 - (c) It is a constituent component of ribosomes
 - (d) All of the above
20. While analysing the DNA of an organism a

total number of 5386 nucleotides were found out of which the proportion of different bases were: Adenine = 29%, Guanine = 17%, Cytosine = 32%, Thymine = 17%. Considering to Chargaff's rule it can be concluded that

- (a) it is a double stranded circular DNA
(b) it is single stranded DNA
(c) it is a double stranded linear DNA
(d) no conclusion can be drawn
21. In some viruses, DNA is synthesised by using RNA as template. Such a DNA is called
(a) A-DNA (b) B-DNA
(c) c DNA (d) r DNA
22. If Meselson and Stahl's experiment is continued for four generations in bacteria, the ratio of $^{15}\text{N}/^{15}\text{N}$: $^{15}\text{N}/^{14}\text{N}$: $^{14}\text{N}/^{14}\text{N}$ containing DNA in the fourth generation would be
(a) 1:1:0 (b) 1:4:0 (c) 0:1:3 (d) 0:1:7
23. If the sequence of nitrogen bases of the coding strand of DNA in a transcription unit is
5' - ATGAATG - 3',
the sequence of bases in its RNA transcript would be;
(a) 5' - AUGAAUG - 3'
(b) 5' - UACUUAC - 3'
(c) 5' - CAUUCAU - 3'
(d) 5' - GUAAGUA - 3'
24. The RNA polymerase holoenzyme transcribes
(a) the promoter, structural gene and the terminator region
(b) the promoter, and the terminator region
(c) the structural gene and the terminator regions
(d) the structural gene only
- [Hint: The transcriptional termination sequences generally share two common features: (i) A palindromic sequence rich in GC base pairs. (ii) A region with consecutive A's on the template strand. Both these regions are transcribed before the release of newly formed RNA chain. The transcript of palindromic sequence forms a hairpin and transcript of oligo-A on DNA has an oligo-U on RNA [Voet&Voet]. Both these regions help in termination. Details of exact mechanism are beyond the scope of our syllabus.]
25. If the base sequence of a codon in mRNA is 5' - AUG - 3', the sequence of tRNA pairing with it must be
(a) 5' - UAC - 3' (b) 5' - CAU - 3'
(c) 5' - AUG - 3' (d) 5' - GUA - 3'
26. The amino acid attaches to the tRNA at its
(a) 5' - end (b) 3' - end
(c) Anti codon site (d) DHU loop
27. To initiate translation, the mRNA first binds to
(a) the smaller ribosomal sub-unit
(b) the larger ribosomal sub-unit
(c) the whole ribosome
(d) no such specificity exists
28. In *E.coli*, the lac operon gets switched on when
(a) Lactose is present and it binds to repressor
(b) Repressor binds to operator
(c) RNA polymerase binds to the operator
(d) Lactose is present and it binds to RNA polymerase

ANSWERS

- | | | | | | |
|---------|---------|---------|---------|---------|---------|
| 1. (b) | 2. (c) | 3. (c) | 4. (c) | 5. (c) | 6. (b) |
| 7. (d) | 8. (d) | 9. (d) | 10. (b) | 11. (c) | 12. (d) |
| 13. (b) | 14. (b) | 15. (b) | 16. (b) | 17. (d) | 18. (a) |
| 19. (d) | 20. (b) | 21. (c) | 22. (d) | 23. (a) | 24. (c) |
| 25. (b) | 26. (b) | 27. (a) | 28. (a) | | |

EVOLUTION

1. Which of the following is used as an atmospheric pollution indicator?
(a) Lepidoptera (b) Lichens
(c) *Lycopersicon* (d) *Lycopodium*
2. The theory of spontaneous generation stated that
(a) life arose from living forms only
(b) life can arise from both living and non-living
(c) Life can arise from non-living things only.
(d) Life arises spontaneously, neither from living nor from the non-living.
3. Animal husbandry and plant breeding programmes are the examples of
(a) reverse evolution
(b) artificial selection
(c) mutation (d) natural selection
4. Palaeontological evidences for evolution refer to the
(a) development of embryo
(b) homologous organs

- (c) fossils
(d) analogous organs
5. The bones of forelimbs of whale, bat, cheetah and man are similar in structure, because
(a) one organism has given rise to another
(b) they share a common ancestor
(c) they perform the same function
(d) they have biochemical similarities
6. Analogous organs arise due to
(a) divergent evolution
(b) artificial selection
(c) genetic drift
(d) convergent evolution
7. $(p + q)^2 = p^2 + 2pq + q^2 = 1$ represents an equation used in
(a) Population genetics
(b) Mendelian genetics
(c) Biometrics
(d) Molecular genetics
8. Appearance of antibiotic-resistant bacteria is an example of
(a) adaptive radiation
(b) transduction
(c) pre-existing variation in the population
(d) divergent evolution
9. Evolution of life shows that life forms had a trend of moving from
(a) Land to water
(b) dryland to wet land
(c) fresh water to sea water
(d) water to land
10. Viviparity is considered to be more evolved because
(a) the young ones are left on their own
(b) the young ones are protected by a thick shell
(c) the young ones are protected inside the mother's body and are looked after they are born leading to more chances of survival
(d) the embryo takes a long time to develop
11. Fossils are generally found in
(a) sedimentary rocks
(b) igneous rocks
(c) metamorphic rocks
(d) any type of rock
12. For the MN-blood group system, the frequencies of M and N alleles are 0.7 and 0.3, respectively. The expected frequency of MN-blood group bearing organisms is likely to be
(a) 42% (b) 49% (c) 9% (d) 58%
13. Which type of selection is industrial melanism observed in moth, *Biston bitularia*?
(a) Stabilising (b) Directional
(c) Disruptive (d) Artificial
14. The most accepted line of descent in human evolution is
(a) Australopithecus → Ramapithecus → Homo sapiens → homo habilis
(b) Homo erectus → Homo habilis → Homo sapiens
(c) Ramapithecus → Homo habilis → Homo erectus → Homo sapiens
(d) Australopithecus → Ramapithecus → Homo erectus → Homo habilis → Homo sapiens
15. Which of the following is an example for link species?
(a) Lobe fish (b) Dodo bird
(c) Sea weed
(d) Tyrannosaurus rex
- [Hint: First exemplar gave the answer (a). Later on it was changed to (d). However, lobe fish seems to be a better answer as it is considered a link between pisces and amphibians].
16. Match the scientists listed under column 'A' with ideas listed column 'B'.
- | | Column I | | Column II |
|------|----------|----|--------------------------------|
| i. | Darwin | M. | abiogenesis |
| ii. | Oparin | N. | use and disuse of organs |
| iii. | Lamarck | O. | continental drift theory |
| iv. | Wagner | P. | evolution by natural selection |
- (a) i-M; ii-P; iii-N; iv-O
(b) i-P; ii-M; iii-N; iv-O
(c) i-N; ii-P; iii-O; iv-M
(d) i-p; ii-O; iii-N; iv-M
17. In 1953 S. L. Miller created primitive earth conditions in the laboratory and gave experimental evidence for origin of first form of life from pre-existing non-living organic molecules. The primitive earth conditions created include

- (a) low temperature, volcanic storms, atmosphere rich in oxygen
 (b) low temperature, volcanic storms, reducing atmosphere
 (c) high temperature, volcanic storms, non-reducing atmosphere
 (d) high temperature, volcanic storms, reducing atmosphere containing CH_4 , NH_3 etc.
18. Variations during mutations of meiotic recombinations are
 (a) random and directionless
 (b) random and directional
 (c) random and small
 (d) random, small and directional

ANSWERS

1. (b) 2. (c) 3. (b) 4. (c) 5. (b) 6. (d)
 7. (a) 8. (c) 9. (d) 10. (c) 11. (a) 12. (a)
 13. (b) 14. (c) 15. (d) 16. (b) 17. (d) 18. (a)

HUMAN HEALTH AND DISEASES

- The term 'Health' is defined in many ways. The most accurate definition of the health would be
 - health is the state of body and mind in a balanced condition
 - health is the reflection of a smiling face
 - health is a state of complete physical, mental and social well-being
 - health is the symbol of economic prosperity.
- The organisms which cause diseases in plants and animals are called
 - pathogens
 - vectors
 - insects
 - worms
- The chemical test that is used for diagnosis of typhoid is
 - ELISA – Test
 - ESR – Test
 - PCR – Test
 - Widal – Test
- Diseases are broadly grouped into infectious and non-infectious diseases. In the list given below, identify the infectious diseases.

i. Cancer	ii. Influenza
iii. Allergy	iv. Small pox
(a) i and ii	(b) ii and iii
(c) iii and iv	(d) ii and iv
- The sporozoites that cause infection when a female *Anopheles* mosquito bites a human being are formed in
 - liver of the person
 - RBCs of mosquito
 - salivary glands of mosquito
 - intestine of mosquito
- The disease *Chikungunya* is transmitted by
 - house flies
 - Aedes* mosquitoes
 - cockroach
 - female *Anopheles*
- Many diseases can be diagnosed by observing the symptoms in the patient. Which group of symptoms are indicative of pneumonia?
 - Difficulty in respiration, fever, chills, cough, headache
 - Constipation, abdominal pain, cramps, blood clots
 - Nasal congestion and discharge, cough, sore throat, headache
 - High fever, weakness, stomach pain, loss of appetite and constipation
- The genes causing cancer are
 - structural genes
 - expressor genes
 - oncogenes
 - regulatory genes
- In malignant tumors, the cells proliferate, grow rapidly and move to other parts of the body to form new tumors. This stage of disease is called
 - metagenesis
 - metastasis
 - teratogenesis
 - mitosis
- When an apparently healthy person is diagnosed as unhealthy by a psychiatrist, the reason could be that
 - the patient was not efficient at his work
 - the patient was not economically prosperous
 - the patient shows behavioural and social maladjustment
 - he does not take interest in sports
- Which of the following are the reason(s) for Rheumatoid arthritis? Choose the correct option.
 - Lymphocytes become more active
 - Body attacks self cells
 - More antibodies are produced in the body
 - The ability to differentiate pathogens or foreign molecules from self cells is lost

- (a) i and ii (b) ii and iv
(c) iii and iv (d) i and iii
12. AIDS is caused by HIV. Among the following, which one is not a mode of transmission of HIV?
(a) Transfusion of contaminated blood
(b) Sharing the infected needles
(c) Shaking hands with infected persons
(d) Sexual contact with infected persons
13. 'Smack' is a drug obtained from the
(a) latex of *Papaver somniferum*
(b) leaves of *Cannabis sativa*
(c) flowers of *Datura*
(d) fruits of *Erythroxyl coca*
14. The substance produced by a cell in viral infection that can protect other cells from further infection is
(a) serotonin (b) colostrum
(c) interferon (d) histamine
15. Transplantation of tissues/organs to save certain patients often fails due to rejection of such tissues/organs by the patient. Which type of immune response is responsible for such rejections?
(a) Auto-immune response
(b) Humoral immune response
(c) Physiological immune response
(d) Cell-mediated immune response
16. Antibodies present in colostrum which protect the new born from certain diseases is of
(a) IgG type (b) IgA type
(c) IgD type (d) IgE type
17. Tobacco consumption is known to stimulate secretion of adrenaline and nor-adrenaline. The component causing this could be
(a) nicotine (b) tannic acid
(c) curaimin (d) catechin
18. Anti venom against snake poison contains
(a) antigens
(b) antigen-antibody complexes
(c) antibodies (d) enzymes
19. Which of the following is not a lymphoid tissue?
(a) Spleen (b) Tonsils
(c) Pancreas (d) Thymus
20. Which of the following glands is large sized at birth but reduces in size with aging?
(a) Pineal (b) Pituitary
(c) Thymus (d) Thyroid
21. Haemozoin is
(a) a precursor of hemoglobin
(b) a toxin released from *Streptococcus* infected cells
(c) a toxin released from *Plasmodium* infected cells
(d) a toxin released from *Haemophilus* infected cells
22. One of the following is not the causal organism for ringworm
(a) *Microsporum* (b) *Trichophyton*
(c) *Epidermophyton* (d) *Macrosporum*
23. A person with sickle cell anemia is
(a) more prone to malaria
(b) more prone to typhoid
(c) less prone to malaria
(d) less prone to typhoid

ANSWERS

- | | | | | | |
|---------|---------|---------|---------|---------|---------|
| 1. (c) | 2. (a) | 3. (d) | 4. (d) | 5. (d) | 6. (b) |
| 7. (a) | 8. (c) | 9. (b) | 10. (c) | 11. (b) | 12. (c) |
| 13. (a) | 14. (c) | 15. (d) | 16. (b) | 17. (a) | 18. (c) |
| 19. (c) | 20. (c) | 21. (c) | 22. (d) | 23. (c) | |

STRATEGIES FOR ENHANCEMENT IN FOOD PRODUCTION

1. The chances of contacting bird flu from a properly cooked (above 100°C) chicken and egg are
(a) very high (b) high
(c) moderate (d) none
2. A group of animals which are related by descent and share many similarities are referred to as
(a) breed (b) race
(c) variety (d) species
3. Inbreeding is carried out in animal husbandry because it
(a) increases vigour
(b) improves the breed
(c) increases heterozygosity
(d) increases homozygosity
4. Sonalika and Kalyan Sona are varieties of
(a) wheat (b) rice
(c) millet (d) tobacco
5. Which one of the following is not a fungal disease?
(a) Rust of wheat

- (b) Smut of Bajra
(c) Black rot of crucifers
(d) Red rot of sugarcane
6. In virus-infected plants the meristematic tissues in both apical and axillary buds are free of virus because
(a) the dividing cells are virus resistant
(b) meristems have anti viral compounds
(c) the cell division of meristems are faster than the rate of viral multiplication
(d) viruses cannot multiply within meristem cell (s)
7. Several South Indian states raise 2-3 crops of rice annually. The agronomic feature that make this possible is because of
(a) shorter rice plant
(b) better irrigation facilities
(c) early yielding rice variety
(d) disease resistant rice variety
8. Which one of the following combination would a sugarcane farmer look for in the sugarcane crop?
(a) Thick stem, long internodes, high sugar content and disease resistant
(b) Thick stem, high sugar content and profuse flowering
(c) Thick stem, short internodes, high sugar content, disease resistant
(d) Thick stem, low sugar content, disease resistant
9. Fungicides and antibiotics are chemicals that
(a) enhance yield and disease resistance
(b) kill pathogenic fungi and bacteria, respectively
(c) kill all pathogenic microbes
(d) kill pathogenic bacteria and fungi respectively
10. Use of certain chemical and radiation to change the base sequences of genes of crop plants is termed
(a) Recombinant DNA technology
(b) Transgenic mechanism
(c) Mutation breeding
(d) Gene therapy
11. The scientific process by which crop plants are enriched with certain desirable nutrients is called
(a) crop protection (b) breeding
(c) bio-fortification
(d) bio-remediation
12. The term 'totipotency' refers to the capacity of a
(a) cell to generate whole plant
(b) bud to generate whole plant
(c) seed to germinate
(d) cell to enlarge in size
13. Given below are a few statements regarding somatic hybridisation. Choose the correct statements.
(i) Protoplasts of different cells of the same plant are fused
(ii) Protoplasts from cells of different species can be fused
(iii) Treatment of cells with cellulose and pectinase is mandatory
(iv) The hybrid protoplast contains characters of only one parental protoplast.
(a) (i) and (iii) (b) (i) and (ii)
(c) (i) and (iv) (d) (ii) and (iii)
14. An explant is
(a) dead plant
(b) part of the plant
(c) part of the plant used in tissue culture
(d) part of the plant that expresses a specific gene
15. The biggest constraint of plant breeding is
(a) availability of desirable gene in the crop and its wild relatives
(b) infrastructure
(c) trained manpower
(d) transfer of genes from unrelated sources.
- [Hint: Both option (a) and ((d), seem to be correct. But, NCERT has mentioned that, "Conventional breeding is often constrained by the availability of limited number of disease resistant genes that are present and identified in various crop varieties or wild relatives." Thus, option (a) seems to be the better answer.]
16. Lysine and tryptophan are
(a) proteins
(b) non-essential amino acids
(c) essential amino acids
(d) aromatic amino acids.
17. Micro-propagation is
(a) propagation of microbes *in vitro*
(b) propagation of plants *in vitro*
(c) propagation of cells *in vitro*
(d) growing plants on smaller scale

18. Protoplast is
 (a) another name for protoplasm
 (b) an animal cell
 (c) a plant cell without a cell wall
 (d) a plant cell
19. To isolate protoplast, one needs
 (a) pectinase (b) cellulase
 (c) both pectinase and cellulase
 (d) chitinase
20. Which one of the following is a marine fish?
 (a) Rohu (b) Hilsa
 (c) Catla (d) Common Carp
21. Which one of the following products of apiculture is used in cosmetics and polishes?
 (a) Honey (b) Oil
 (c) Wax (d) Royal jelly
22. More than 70 per cent of livestock population is in
 (a) Denmark (b) India
 (c) China (d) India and China
23. The agriculture sector of India employs
 (a) 50 per cent of the population
 (b) 70 per cent of the population
 (c) 30 per cent of the population
 (d) 60 per cent of the population
24. 33 percent of India's (Gross Domestic Product) comes from
 (a) industry (b) agriculture
 (c) export
 (d) small-scale cottage industries
25. A collection of all the alleles of all the genes of a crop plant is called
 (a) germplasm collection
 (b) protoplasm collection
 (c) herbarium
 (d) somaclonal collection

ANSWERS

1. (d) 2. (a) 3. (d) 4. (a) 5. (c) 6. (c)
 7. (c) 8. (a) 9. (b) 10. (c) 11. (c) 12. (a)
 13. (d) 14. (c) 15. (d) 16. (c) 17. (b) 18. (c)
 19. (c) 20. (b) 21. (c) 22. (d) 23. (d) 24. (b)
 25. (a)

MICROBES IN HUMAN WELFARE

1. The vitamin whose content increases following the conversion of milk into curd by lactic acid bacteria is

- (a) vitamin C (b) vitamin D
 (c) vitamin B₁₂ (d) vitamin E.
2. Wastewater treatment generates a large quantity of sludge, which can be treated by
 (a) digesters
 (b) activated sludge
 (c) chemicals (d) oxidation pond
3. Methanogenic bacteria are not found in
 (a) rumen of cattle
 (b) gobar gas plant
 (c) bottom of water-logged paddy fields
 (d) activated sludge
4. Match the following list of bacteria and their commercially important products

Bacterium	Product
(i) <i>Aspergillus niger</i>	(a) Lactic acid
(ii) <i>Acetobacter aceti</i>	(b) Butyric acid
(iii) <i>Clostridium butylicum</i>	(c) Acetic acid
(iv) <i>Lactobacillus</i>	(d) Citric acid

Choose the correct match

- (a) i b, ii c, iii d, iv a
 (b) i b, ii d, iii c, iv a
 (c) i d, ii c, iii b, iv a
 (d) i d, ii a, iii c, iv b
5. Match the following list of bioactive substances and their roles

Bioactive Substance	Role
(i) Statin	(a) Removal of oil stains
(ii) Cyclosporin A	(b) Removal of clots from blood vessels
(iii) Streptokinase	(c) Lowering of blood cholesterol
(iv) Lipase	(d) Immunosuppressive agent

Choose the correct match

- (a) i b, ii c, iii a, iv d
 (b) i d, ii b, iii a, iv c
 (c) i d, ii a, iii b, iv c
 (d) i c, ii d, iii b, iv a
6. The primary treatment of waste water involves the removal of
 (a) dissolved impurities

- (b) stable particles
(c) toxic substances
(d) harmful bacteria
7. BOD of waste water is estimated by measuring the amount of
(a) Total organic matter
(b) Biodegradable organic matter
(c) Oxygen evolution
(d) Oxygen consumption
8. Which one of the following alcoholic drinks is produced without distillation?
(a) Wine (b) Whisky
(b) Rum (d) Brandy
9. The technology of biogas production from cow dung was developed in India largely due to the efforts of
(a) Gas Authority of India
(b) Oil and Natural Gas Commission
(c) Indian Agricultural Research Institute and Khadi & Village Industries Commission
(d) Indian Oil Corporation
10. The free-living fungus *Trichoderma* can be used for
(a) killing insects
(b) biological control of plant diseases
(c) controlling butterfly caterpillars
(d) producing antibiotics
11. What would happen if oxygen availability to activated sludge flocs is reduced?
(a) It will slow down the rate of degradation of organic matter
(b) The center of flocs will become anoxic, which would cause death of bacteria and eventually breakage of flocs.
(c) Flocs would increase in size as anaerobic bacteria would grow around flocs.
(d) Protozoa would grow in large numbers
12. Mycorrhiza does not help the host plant in
(a) enhancing its phosphorus uptake capacity
(b) increasing its tolerance to drought
(c) enhancing its resistance to root pathogens
(d) increasing its resistance to insects
13. Which one of the following is not a nitrogen-fixing organism?
(a) *Anabaena* (b) *Nostoc*
(c) *Azotobacter* (d) *Pseudomonas*
14. Big holes in Swiss cheese are made by a
(a) a machine
(b) a bacterium that produces methane gas
(c) a bacterium producing a large amount of carbon dioxide
(d) a fungus that releases a lot of gases during its metabolic activities
15. The residue left after methane production from cattle dung is
(a) burnt
(b) buried in land fills
(c) used as manure
(d) used in civil construction
16. Methanogens do not produce
(a) oxygen
(b) methane
(c) hydrogen sulphide
(d) carbon dioxide
17. Activated sludge should have the ability to settle quickly so that it can
(a) be rapidly pumped back from sedimentation tank to aeration tank
(b) absorb pathogenic bacteria present in waste water while sinking to the bottom of the settling tank
(c) be discarded and anaerobically digested
(d) absorb colloidal organic matter.
18. Match the items in Column 'A' and Column 'B' and choose correct answer.
- | Column A | Column B |
|--------------------------|------------------------|
| (i) Lady bird | (a) Methano bacterium |
| (ii) Mycorrhiza | (b) <i>Trichoderma</i> |
| (iii) Biological control | (c) Aphids |
| (iv) Biogas | (d) <i>Glomus</i> |
- The correct answer is
(a) i b, ii d, iii c, iv a
(b) i c, ii d, iii b, iv a
(c) i d, ii a, iii b, iv c
(d) i c, ii b, iii a, iv d
- | ANSWERS | | | | | |
|---------|---------|---------|---------|---------|---------|
| 1. (c) | 2. (a) | 3. (d) | 4. (c) | 5. (d) | 6. (b) |
| 7. (d) | 8. (a) | 9. (c) | 10. (b) | 11. (b) | 12. (d) |
| 13. (d) | 14. (c) | 15. (c) | 16. (a) | 17. (a) | 18. (b) |

BIOTECHNOLOGY: PRINCIPLES AND PROCESSES

- Rising of dough is due to
 - multiplication of yeast
 - production of CO_2
 - emulsification
 - hydrolysis of wheat flour starch into sugars
- An enzyme catalysing the removal of nucleotides from the ends of DNA is
 - endonuclease
 - exonuclease
 - DNA ligase
 - Hind – II
- The transfer of genetic material from one bacterium to another through the mediation of a vector like virus is termed as
 - transduction
 - conjugation
 - transformation
 - translation
- Which of the given statement is correct in the context of observing DNA separated by agarose gel electrophoresis?
 - DNA can be seen in visible light
 - DNA can be seen without staining in visible light
 - Ethidium bromide stained DNA can be seen in visible light
 - Ethidium bromide stained DNA can be seen under exposure to UV light
- 'Restriction' in Restriction enzyme refers to
 - cleaving of phosphodiester bond in DNA by the enzyme
 - cutting of DNA at specific position only
 - prevention of the multiplication of bacteriophage in bacteria
 - all of the above
- Which of the following is not required in the preparation of a recombinant DNA molecule?
 - Restriction endonuclease
 - DNA ligase
 - DNA fragments
 - E. coli*
- In agarose gel electrophoresis, DNA molecules are separated on the basis of their:
 - charge only
 - size only
 - charge to size ratio
 - all of the above
- The most important feature in a plasmid to be used as a vector is
 - origin of replication (ori)
 - presence of a selectable marker
 - presence of sites for restriction endonuclease
 - its size
- While Isolating DNA from bacteria which of the following enzymes is not used?
 - Lysozyme
 - Ribonuclease
 - Deoxyribonuclease
 - Protease
- Which of the following has popularised the PCR (Polymerase chain reaction)?
 - Easy availability of DNA template
 - Availability of synthetic primers
 - Availability of cheap deoxyribonucleotides
 - Availability of 'Thermostable' DNA polymerase
- An antibiotic resistance gene in a vector usually helps in the selection of
 - competent cells
 - transformed cells
 - recombinant cells
 - none of the above
- Significance of 'heat shock' method in bacterial transformation is to facilitate
 - binding of DNA to the cell wall
 - uptake of DNA through membrane transport proteins
 - uptake of DNA through transient pores in the bacterial cell wall
 - expression of antibiotic resistance gene
- The role of DNA ligase in the construction of a recombinant DNA molecule is
 - formation of phosphodiester bond between two DNA fragments
 - formation of hydrogen-bonds between sticky ends of DNA fragments
 - ligation of all purine and pyrimidine bases
 - none of the above
- Which of the following bacteria is not a source of restriction endonuclease?
 - Haemophilus influenzae*
 - Escherichia coli*
 - Entamoeba coli*
 - Bacillus amyloliquifaciens*
- Which of the following steps are catalysed by Taq polymerase in a PCR reaction?
 - Denaturation of template DNA
 - Annealing of primers to template DNA

- (c) Extension of primer end on the template DNA
(d) All of the above
16. A bacterial cell was transformed with a recombinant DNA that was generated using a human gene. However, the transformed cells did not produce the desired protein. Reasons could be
(a) human gene may have intron which bacteria cannot process
(b) amino acid codons for humans and bacteria are different
(c) human protein is formed but degraded by bacteria
(d) all of the above
17. Which of the following should be chosen for best yield if one were to produce a recombinant protein in large amounts?
(a) Laboratory flask of largest capacity
(b) A stirred tank bioreactor without inlets and outlets
(c) A continuous culture system
(d) Any of the above
18. Who among the following was awarded the Nobel Prize for the development of PCR technique?
(a) Herbert Boyer
(b) Hargovind Khurana
(c) Kary Mullis
(d) Arthur Kornberg
19. Which of the following statements does not hold true for restriction enzyme?
(a) It recognises a palindromic nucleotide sequence
(b) It is an endonuclease
(c) It is isolated from viruses
(d) It produces the same kind of sticky ends in different DNA molecules
2. C-peptide of human insulin is
(a) a part of mature insulin molecule
(b) responsible for formation of disulphide bridges
(c) removed during maturation of pro-insulin to insulin
(d) responsible for its biological activity
3. GEAC stands for
(a) Genome Engineering Action Committee
(b) Ground Environment Action Committee
(c) Genetic Engineering Approval Committee
(d) Genetic and Environment Approval Committee
4. α -1 antitrypsin is
(a) an antacid (b) an enzyme
(c) used to treat arthritis
(d) used to treat emphysema
5. A probe which is a molecule used to locate specific sequences in a mixture of DNA or RNA molecules could be
(a) a single stranded RNA
(b) a single stranded DNA
(c) either RNA or DNA
(d) can be ss DNA but not ss RNA
6. Choose the correct option regarding Retrovirus.
(a) An RNA virus that can synthesise DNA during infection
(b) A DNA virus that can synthesise RNA during infection
(c) A ssDNA virus (d) A dsRNA virus
7. The site of production of ADA in the body is
(a) bone marrow (b) lymphocytes
(c) blood plasma (d) monocytes
8. Aprotaxin is
(a) a primitive toxin
(b) a denatured toxin
(c) toxin produced by protozoa
(d) inactive toxin
9. Pathophysiology is the
(a) study of physiology of pathogen
(b) study of normal physiology of host
(c) study of altered physiology of host
(d) none of the above
10. The trigger for activation of toxin of *Bacillus thuringiensis* is
(a) acidic pH of stomach
(b) high temperature

ANSWERS

1. (b) 2. (b) 3. (a) 4. (d) 5. (c) 6. (d)
7. (b) 8. (a) 9. (c) 10. (d) 11. (b) 12. (c)
13. (a) 14. (c) 15. (c) 16. (a) 17. (c) 18. (c)
19. (c)

BIOTECHNOLOGY AND ITS APPLICATIONS

1. Bt cotton is not
(a) a GM plant
(b) insect resistant
(c) a bacterial gene expressing system
(d) resistant to all pesticides

10. The trigger for activation of toxin of *Bacillus thuringiensis* is
(a) acidic pH of stomach
(b) high temperature

- (c) alkaline pH of gut
(d) mechanical action in the insect gut
11. Golden rice is
(a) a variety of rice grown along the yellow river in China
(b) long stored rice having yellow colour tint
(c) a transgenic rice having gene for carotene
(d) wild variety of rice with yellow coloured grains
12. In RNAi, genes are silenced using
(a) ss DNA (b) ds DNA
(c) ds RNA (d) ss RNA
13. The first clinical gene therapy was done for the treatment of
(a) AIDS (b) Cancer
(c) Cystic fibrosis
(d) SCID (Severe Combined Immuno Deficiency resulting from deficiency of AD(A))
14. ADA is an enzyme which is deficient in a genetic disorder SCID. What is the full form of ADA?
(a) Adenosine deoxy aminase
(b) Adenosine deaminase
(c) Aspartate deaminase
(d) Arginine deaminase
15. Silencing of a gene could be achieved through the use of
(a) RNAi only
(b) antisense RNA only
(c) both RNAi and antisense RNA
(d) none of the above

ANSWERS

1. (d) 2. (c) 3. (c) 4. (d) 5. (c) 6. (a)
7. (b) 8. (d) 9. (c) 10. (c) 11. (c) 12. (c)
13. (d) 14. (b) 15. (c)

ORGANISMS AND POPULATIONS

1. Autecology is the
(a) relation of a population to its environment
(b) relation of an individual to its environment
(c) relation of a community to its environment
(d) relation of a biome to its environment

[Hint: Exemplar gives the answer as (b) but, Autecology is the study of reciprocal relationships between every stage of development of a population/

species/ individual and its environment. Thus both (a) and (b) are correct.]

2. Ecotone is
(a) a polluted area
(b) the bottom of a lake
(c) a zone of transition between two communities
(d) a zone of developing community
3. Biosphere is
(a) a component in the ecosystem
(b) composed of the plants present in the soil
(c) life in the outer space
(d) composed of all living organisms present on earth which interact with the physical environment
4. Ecological niche is
(a) the surface area of the ocean
(b) an ecologically adapted zone
(c) the physical position and functional role of a species within the community
(d) formed of all plants and animals living at the bottom of a lake
5. According to Allen's Rule, the mammals from colder climates have
(a) shorter ears and longer limbs
(b) longer ears and shorter limbs
(c) longer ears and longer limbs
(d) shorter ears and shorter limbs
6. Salt concentration (Salinity) of the sea measured in parts per thousand is
(a) 10 – 15 (b) 30 – 70
(c) 0 – 5 (d) 30 – 35
7. Formation of tropical forests needs mean annual temperature and mean annual precipitation as
(a) 18 - 25°C and 150 – 400 cm
(b) 5 - 15°C and 50 – 100 cm
(c) 30 - 50°C and 100 – 150 cm
(d) 5 - 15°C and 100 – 200 cm

[Hint:

S.No	Forest Type	Mean Annual Temperature	Mean Annual Rain fall
1.	Tropical Rain Forest	23 - 27°C	200 - 350 cm
2.	Tropical Deciduous Forest	22 - 32°C	90 - 160 cm
3.	Temperate Forest Broad Leaved	6 - 20°C	100 - 250 cm
4.	Temperate Forest Needle Leaved	6 - 15°C	50 - 170 cm

8. Which of the following forest plants controls the light conditions at the ground?
(a) Lianas and climbers (b) Shrubs
(c) Tall tree (d) Herbs
9. What will happen to a well growing herbaceous plant in the forest if it is transplanted outside the forest in a park?
(a) It will grow normally
(b) It will grow well because it is planted in the same locality
(c) It may not survive because of change in its micro climate
(d) It grows very well because the plant gets more sunlight
10. If a population of 50 *Paramoecium* present in a pool increases to 150 after an hour, what would be the growth rate of population?
(a) 50 per hour (b) 200 per hour
(c) 5 per hour (d) 100 per hour
11. What would be the per cent growth or birth rate per individual per hour for the same population mentioned in the previous question (Question 10)?
(a) 100 (b) 200 (c) 50 (d) 150
12. A population has more young individuals compared to the older individuals. What would be the status of the population after some years?
(a) It will decline (b) It will stabilise
(c) It will increase
(d) It will first decline and then stabilise
13. What parameters are used for tiger census in our country's national parks and sanctuaries?
(a) Pug marks only
(b) Pug marks and faecal pellets
(c) Faecal pellets only
(d) Actual head counts
14. Which of the following would necessarily decrease the density of a population in a given habitat?
(a) Natality > mortality
(b) Immigration > emigration
(c) Mortality and emigration
(d) Natality and immigration
15. A protozoan reproduces by binary fission. What will be the number of protozoans in its population after six generations?
(a) 128 (b) 24 (c) 64 (d) 32
16. In 2005, for each of the 14 million people present in a country, 0.028 were born and 0.008 died during the year. Using exponential equation, the number of people present in 2015 is predicted as
(a) 25 millions (b) 17 millions
(c) 20 millions (d) 18 millions
- [Hint: Use the formula for the exponential growth curve : $\frac{dN}{dt} = (b - d) N$]
17. Amensalism is an association between two species where
(a) one species is harmed and other is benefitted
(b) one species is harmed and other is unaffected
(c) one species is benefitted and other is unaffected
(d) both the species are harmed
18. Lichens are the association of
(a) Bacteria and fungus
(b) Algae and bacterium
(c) Fungus and algae
(d) Fungus and virus
19. Which of the following is a partial root parasite?
(a) Sandal wood (b) *Mistletoe*
(c) *Orobanch* (d) *Gonoderma*
- [Hint: • Sandal wood is a partial root parasite.
• *Mistletoe* is a partial stem parasite.
• *Orobanch* is a total root parasite.
• *Gonoderma* is a wood rotting fungi.]
20. Which one of the following organisms reproduces sexually only once in its life time?
(a) Banana plant (b) Mango
(c) Tomato (d) *Eucalyptus*
- [Hint: Tomato is an annual plant and it reproduces sexually only once in its life time. Thus the correct answer is (c) tomato.]

ANSWERS

1. (b) 2. (c) 3. (d) 4. (c) 5. (d) 6. (d)
7. (a) 8. (c) 9. (c) 10. (d) 11. (b) 12. (c)
13. (b) 14. (c) 15. (c) 16. (b) 17. (b) 18. (c)
19. (a) 20. (d)

ECOSYSTEM

1. Decomposers like fungi and bacteria are
(i) autotrophs (ii) heterotrophs
(iii) saprotrophs
(iv) chemo-autotrophs
Choose the correct answer
(a) (i) and (iii) (b) (i) and (iv)
(c) (ii) and (iii) (d) (i) and (ii)

2. The process of mineralisation by micro organisms helps in the release of
 - (a) inorganic nutrients from humus
 - (b) both organic and inorganic nutrients from detritus
 - (c) organic nutrients from humus
 - (d) inorganic nutrients from detritus and formation of humus
 3. Productivity is the rate of production of biomass expressed in terms of
 - (i) $(\text{kcal m}^{-3}) \text{ yr}^{-1}$ (ii) $\text{g}^{-2} \text{ yr}^{-1}$
 - (iii) $\text{g}^{-1} \text{ yr}^{-1}$ (iv) $(\text{kcal m}^{-2}) \text{ yr}^{-1}$
 - (a) (ii) (b) (iii)
 - (c) (ii) and (iv) (d) (i) and (iii)
 4. An inverted pyramid of biomass can be found in which ecosystem?
 - (a) Forest (b) Marine
 - (c) Grass land (d) Tundra
 5. Which of the following is not a producer?
 - (a) *Spirogyra* (b) *Agaricus*
 - (c) *Volvox* (d) *Nostoc*
 6. Which of the following ecosystems is most productive in terms of net primary production?
 - (a) Deserts
 - (b) Tropical rain forests
 - (c) Oceans (d) Estuaries
- [Hint: Gross primary productivity of tropical rain forests & estuaries is 20,000 Kcal/ m^2 /year. Total area of estuaries and reefs is estimated to be $2 \times 10^6 \text{ Km}^2$ while that of tropical & subtropical rain forests is $14.7 \times 10^6 \text{ Km}^2$. Thus, because of larger area the total production of tropical rain forests comes out to be much higher than that of estuaries.]
7. Pyramid of numbers is
 - (a) always upright
 - (b) always inverted
 - (c) either upright or inverted
 - (d) neither upright nor inverted
 8. Approximately how much of the solar energy that falls on the leaves of a plant is converted to chemical energy by photosynthesis?
 - (a) Less than 1% (b) 2 – 10%
 - (c) 30% (d) 50%
 9. Among the following, where do you think the process of decomposition would be the fastest?
 - (a) Tropical rain forest (b) Antarctic
 - (c) Dry arid region (d) Alpine region
 10. How much of the net primary productivity of a terrestrial ecosystem is eaten and digested by herbivores?
 - (a) 1% (b) 10% (c) 40% (d) 90%
 11. During the process of ecological succession the changes that take place in communities are
 - (a) orderly and sequential
 - (b) random
 - (c) very quick
 - (d) not influenced by the physical environment
 12. Climax community is in a state of
 - (a) non-equilibrium (b) equilibrium
 - (c) disorder (d) constant change
 13. Among the following bio-geo-chemical cycles which one does not have losses due to respiration?
 - (a) Phosphorus (b) Nitrogen
 - (c) Sulphur (d) All of the above
 14. The sequence of communities of primary succession in water is
 - (a) phytoplankton, sedges, free-floating hydrophytes, rooted hydrophytes, grasses and trees.
 - (b) phytoplankton, free-floating hydrophytes, rooted hydrophytes, sedges, grasses and trees.
 - (c) free-floating hydrophytes, sedges, phytoplankton, rooted hydrophytes, grasses and trees.
 - (d) phytoplankton, rooted submerged hydrophytes, floating hydrophytes, reed swamp, sedges, meadow and trees.
 15. The reservoir for the gaseous type of bio-geo chemical cycle exists in
 - (a) stratosphere (b) atmosphere
 - (c) ionosphere (d) lithosphere
 16. If the carbon atoms fixed by producers already have passed through three species, the trophic level of the last species would be
 - (a) scavenger
 - (b) tertiary producer
 - (c) tertiary consumer
 - (d) secondary consumer
 17. Which of the following type of ecosystem is expected in an area where evaporation exceeds precipitation, and mean annual rainfall is below 100mm?
 - (a) Grassland (b) Shrubby forest
 - (c) Desert (d) Mangrove
 18. The zone at the edge of a lake or ocean

which is alternatively exposed to air and immersed in water is called

- (a) pelagic zone (b) benthic zone
(c) lentic zone (d) littoral zone

19. Edaphic factor refers to

- (a) water (b) soil
(c) relative humidity (d) altitude

20. Which of the following is an ecosystem service provided by a natural ecosystem?

- (a) Cycling of nutrients
(b) Prevention of soil erosion
(c) Pollutant absorption and reduction of the threat of global warming
(d) All of the above

ANSWERS

1. (c) 2. (a) 3. (c) 4. (b) 5. (b) 6. (b)
7. (c) 8. (b) 9. (a) 10. (b) 11. (a) 12. (b)
13. (d) 14. (d) 15. (b) 16. (c) 17. (c) 18. (d)
19. (b) 20. (d)

BIODIVERSITY & CONSERVATION

1. Which of the following countries has the highest biodiversity?

- (a) Brazil (b) South Africa
(c) Russia (d) India

2. Which of the following is not a cause for loss of biodiversity?

- (a) Destruction of habitat
(b) Invasion by alien species
(c) Keeping animals in Zoological parks
(d) Over-exploitation of natural resources

3. Which of the following is not an invasive alien species in the Indian context?

- (a) *Lantana* (b) *Cynodon*
(c) *Parthenium* (d) *Eichhornia*

4. Where among the following will you find pitcher plant?

- (a) Rain forest of North-East India
(b) Sunderbans
(c) Thar Desert (d) Western Ghats

[Hint: It is commonly found in forests of Assam.]

5. Which one of the following is not a major characteristic feature of biodiversity hot spots?

- (a) Large number of species
(b) Abundance of endemic species
(c) Large number of exotic species
(d) Destruction of habitat

[Hint: Exemplar gives the answer as (d) but the correct answer as per the facts mentioned in NCERT (Text book) should be (c).]

6. Match the animals given in column A with their location in column B

Column A	Column B
(i) Dodo	(a) Africa
(ii) Quagga	(b) Russia
(iii) Thylacine	(c) Mauritius
(iv) Stellar's sea cow	(d) Australia

Choose the correct match from the following

- (a) i-a, ii-c, iii-b, iv-d
(b) i-d, ii-c, iii-a, iv-b
(c) i-c, ii-a, iii-b, iv-d
(d) i-c, ii-a, iii-d, iv-b

7. What is common to the following plants? *Nepenthes*, *Psilotum*, *Rauwolfia* and *Aconitum*

- (a) All are ornamental plants
(b) All are phylogenetic link species
(c) All are prone to over exploitation
(d) All are exclusively present in the Eastern Himalayas

[Hint: *Rauwolfia*, *Aconitum* & *Podophyllum* are medicinal plants which have been overexploited and are endangered now from their natural habitats. Botanical tours often lead to mass collection of rare plants from their small area of occurrence like *Psilotum* & *Nepenthes*.]

8. The one-horned rhinoceros is specific to which of the following sanctuary?

- (a) Bhitarkanika (b) Bandipur
(c) Kaziranga (d) Corbett park

9. Amongst the animal groups given below, which one has the highest percentage of endangered species?

- (a) Insects (b) Mammals
(c) Amphibians (d) Reptiles

10. Which one of the following is an endangered plant species of India?

- (a) *Rauwolfia serpentina*
(b) *Santalum album* (Sandal wood)
(c) *Cycas beddomei*
(d) All of the above

[Hint: *Rauwolfia serpentina* is mainly found in Himalayas & Eastern India. Rest two are mainly found in Peninsular India.]

11. What is common to *Lantana*, *Eichhornia* and African catfish?

- (a) All are endangered species of India
(b) All are key stone species
(c) All are mammals found in India
(d) All the species are neither threatened nor indigenous species of India

12. The extinction of passenger pigeon was due to
 (a) increased number of predatory birds
 (b) over exploitation by humans
 (c) non-availability of the food
 (d) bird flu virus infection
13. Which of the following statements is correct?
 (a) *Parthenium* is an endemic species of our country
 (b) African catfish is not a threat to indigenous catfishes
 (c) Steller's sea cow is an extinct animal
 (d) *Lantana* is popularly known as carrot grass.
14. Among the ecosystem mentioned below, where can one find maximum biodiversity?
 (a) Mangroves (b) Desert
 (c) Coral reefs (d) Alpine meadows
15. Which of the following forests is known as the 'lungs of the planet Earth'?
 (a) Tiaga forest (b) Tundra forest
 (c) Amazon rain forest
 (d) Rain forests of North East India
16. The active chemical drug reserpine is obtained from
 (a) *Datura* (b) *Rauwolfia*
 (c) *Atropa* (d) *Papaver*
17. Which of the following groups exhibits more species diversity?
 (a) Gymnosperms (b) Algae
 (c) Bryophytes (d) Fungi
18. Which of the below mentioned regions exhibit less seasonal variations?
 (a) Tropics (b) Temperates
 (c) Alpines (d) Both (a) & (b)
19. The historic convention on Biological Diversity held in Rio de Janeiro in 1992 is known as
 (a) CITES Convention
 (b) The Earth Summit
 (c) G-16 Summit (d) MAB Programme
20. What is common to the techniques (i) *in vitro* fertilisation (ii) Cryo preservation and (iii) tissue culture?
 (a) All are in situ conservation methods
 (b) All are ex situ conservation methods
 (c) All require ultra modern equipment and large space
 (d) All are methods of conservation of extinct organisms

ANSWERS

- | | | | | | |
|---------|---------|---------|---------|---------|---------|
| 1. (a) | 2. (c) | 3. (b) | 4. (a) | 5. (d) | 6. (d) |
| 7. (c) | 8. (c) | 9. (c) | 10. (d) | 11. (d) | 12. (b) |
| 13. (c) | 14. (c) | 15. (c) | 16. (b) | 17. (d) | 18. (a) |
| 19. (b) | 20. (b) | | | | |

ENVIRONMENTAL ISSUES

1. Non-biodegradable pollutants are created by
 (a) nature
 (b) excessive use of resources
 (c) humans (d) natural disasters
2. According to the Central Pollution Control Board, particles that are responsible for causing great harm to human health are of diameter
 (a) 2.50 micrometers
 (b) 5.00 micrometers
 (c) 10.00 micrometers
 (d) 7.5 micrometers
3. The material generally used for sound proofing of rooms like a recording studio and auditorium, etc. is
 (a) cotton (b) coir
 (c) wood (d) styro foam
4. Compressed Natural Gas (CNG) is
 (a) propane (b) methane
 (c) ethane (d) butane
5. World's most problematic aquatic weed is
 (a) *Azolla* (b) *Wolffia*
 (c) *Eichornia* (d) *Trapa*
6. Which of the following causes biomagnification?
 (a) SO_2 (b) Mercury
 (c) DDT (d) Both (b) & (c)
7. The expanded form of DDT is
 (a) dichloro diphenyl trichloroethane
 (b) dichloro diethyl trichloroethane
 (c) dichloro dipyrydyl trichloroethane
 (d) dichloro diphenyl tetrachloroacetate
8. Which of the following material takes the longest time for biodegradation?
 (a) Cotton (b) Paper
 (c) Bone (d) Jute
9. Choose the incorrect statement.
 (a) The Montreal protocol is associated with the control of emission of ozone depleting substances
 (b) Methane and carbon dioxide are green house gases

- (c) Dobson units are used to measure oxygen content
(d) Use of incinerators is crucial to disposal of hospital wastes
10. Among the following which one causes more indoor chemical pollution?
(a) Burning coal
(b) Burning cooking gas
(c) Burning mosquito coil
(d) Room spray
11. The green scum seen in the fresh water bodies is
(a) Blue green algae (b) Red algae
(c) Green algae (d) Both (a) and (c)
12. The loudness of a sound that a person can withstand without discomfort is about
(a) 150 dB (b) 215 dB
(c) 30 dB (d) 80 dB
13. The major source of noise pollution, world wide is due to
(a) office equipment
(b) transport system
(c) sugar, textile and paper industries
(d) oil refineries and thermal power plants

14. Match correctly the following and choose the correct option

i.	Environment Protection Act	A.	1974
ii.	Air Prevention & Control of Pollution Act	B.	1987
iii.	Water Act	C.	1986
iv.	Amendment of Air Act to include noise	D.	1981

The correct matches is

- (a) i-C, ii-D, iii-A, iv-B
(b) i-A, ii-C, iii-B, iv-D
(c) i-D, ii-A, iii-B, iv-C
(d) i-C, ii-D, iii-B, iv-A
15. Catalytic converters are fitted into automobiles to reduce emission of harmful gases. Catalytic converters change unburnt hydrocarbons into
(a) carbon dioxide and water
(b) carbon monoxide
(c) methane
(d) carbon dioxide and methane
16. Why is it necessary to remove sulphur from petroleum products?
(a) To reduce the emission of sulphur dioxide in exhaust fumes

- (b) To increase efficiency of automobile engines
(c) To use sulphur removed from petroleum for commercial purposes
(d) To increase the life span of engine silencers
17. Which one of the following impurities is easiest to remove from waste water?
(a) Bacteria (b) Colloids
(c) Dissolved solids
(d) Suspended solids
18. Which one of the following diseases is not due to contamination of water?
(a) Hepatitis-B (b) Jaundice
(c) Cholera (d) Typhoid
19. Nuisance growth of aquatic plants and bloom-forming algae in natural waters is generally due to high concentrations of
(a) carbon (b) sulphur
(c) calcium (d) phosphorus
20. Algal blooms impart a distinct colour to water due to
(a) their pigments
(b) excretion of coloured substances
(c) formation of coloured chemicals in water facilitated by physiological degradation of algae
(d) absorption of light by algal cell wall
21. Match the items in column I and column II and choose the correct option

Column I	Column II
A. UV	i. Biomagnification
B. Biodegradable organic matter	ii. Eutrophication
C. DDT	iii. Snow blindness
D. Phosphates	iv. BOD

- (a) A ii, B i, C iv, D iii
(b) A iii, B ii, C iv, D i
(c) A iii, B iv, C i, D ii
(d) A iii, B i, C iv, D ii
22. In the textbook you came across Three Mile Island and Chernobyl disasters associated with accidental leakage of radioactive wastes. In India we had Bhopal gas tragedy. It is associated with which of the following?
(a) CO_2 (b) Methyl Iso-Cyanate
(c) CFC's (d) Methyl Cyanate

ANSWERS

1. (c) 2. (a) 3. (d) 4. (b) 5. (c) 6. (d)
7. (a) 8. (c) 9. (c) 10. (a) 11. (d) 12. (d)
13. (b) 14. (a) 15. (a) 16. (a) 17. (d) 18. (a)
19. (d) 20. (a) 21. (c) 22. (b)